



3 FREE DIGITAL BOOKS

HISTORY OF NASA • EVENTS THAT CHANGED THE WORLD • 60 SECOND SCIENCE

WORTH
£30

ON BOARD A
TOP-SECRET
SPACE
SHUTTLE

INSIDE
YOUR COMET
NEOWISE IMAGES

All About Space

THE CRASH THAT MADE

OUR MOON

Secrets of a Solar System
collision that sparked
life on Earth

+
NEW IMAGE
SPACE'S BIGGEST STAR

INSTANT EXPERT
WHAT IS ZODIACIAL LIGHT?



APOLLO 11'S FIRST MAN

The story of Neil Armstrong's
daring astronaut training



REVEALED

ALIEN CONTACT ACTION PLAN

EINSTEIN CHALLENGED

IS SPACE-TIME THEORY WRONG?

NASA PHOTOS OUR SUN AS YOU'VE NEVER SEEN IT BEFORE



OUR LEGACY OF INNOVATION CONTINUES

StarSense EXPLORER™

Award-Winning Sky Recognition Technology

Celestron's revolutionary StarSense Explorer telescope and companion app have reinvented the manual telescope, opening up the hobby of astronomy for a new generation. At the heart of the system is StarSense Explorer's sky recognition and sky mapping capability. Simply place your smartphone into the unique StarSense dock and launch the app. The app uses your smartphone to very accurately determine its pointing position by "plate solving"—the same method professional observatories and orbiting satellites use to calculate their positions.

The StarSense Explorer app, developed in collaboration with Simulation Curriculum, tells you exactly which celestial objects are currently visible in the night sky and where to move your telescope to place those objects in the telescope's eyepiece. What's more, you can access detailed information and even audio descriptions for the most popular objects while you observe. No prior knowledge of the night sky is required.

Learn more about the amazing technology behind StarSense Explorer at celestron.com/sky-recognition



StarSense Explorer LT 114AZ

SRP £199.99



StarSense Explorer LT 80AZ

SRP £179.99



StarSense Explorer DX 130

SRP £379.99



StarSense Explorer DX 102

SRP £349.99

Find out more at celestron.com Or contact Celestron in the UK on 0118 4671 200

Comet NEOWISE

All eyes have been on comet
C/2020 F3 (NEOWISE) this month



Welcome

As I write this, I've just come back from a successful early morning session

observing Comet NEOWISE. It's currently glowing at magnitude +3, slightly dimmer than when I first pointed my camera at it a few nights ago. Even without optical aid the comet is an incredible naked-eye sight, visible even in areas of moderate light pollution. Did you manage to spot it?

According to the **All About Space** e-mail inbox and social channels, we've discovered that many of you did, and this issue we've featured your spectacular images as part of our picture gallery on page 6. If you missed our call for submissions, then not to worry - we're still accepting your images of NEOWISE over the next few issues. Details of our social

channels can be found below and over on our contents page.

Elsewhere in the magazine, new research suggests that the details of how our Moon formed could be different to how we initially envisaged. Will the history of our Solar System need to be rewritten? Turn to page 14 for the full details.

Over on page 42, our special report reveals Earth's action plan on what will happen when - of if - we make contact with intelligent alien life. Find out how us earthlings will be informed by officials, what the steps will be and what will happen if it turns out that our alien counterparts are less than friendly...

Enjoy the issue, see you soon!

Gemma Lavender
Editor-in-Chief

Our contributors include...



Colin Stuart
Space science writer
If we can get a true understanding of how our natural satellite was made, we could uncover how we came to thrive on Earth. Colin has the details on page 14.



Chris Hadfield
Former astronaut
Chris Hadfield answers your space questions alongside our expert panel of astronomers, astrophysicists and space exploration experts on page 64.



Nour Raouafi
Astrophysicist
The project scientist of NASA's Parker Solar Probe reveals the latest results, images and what's next for the craft - and how the next decade is the golden age for solar research.



Lee Cavendish
Staff writer
How big is supergiant Antares? Lee reveals the brand-new images from the Very Large Array that have provided a new look at the red gem that lies in Scorpius.

ALL ABOUT SPACE ISSUE 108 ON SALE 10 SEPTEMBER!

Available from supermarkets, newsagents and
online at myfavouritemagazines.co.uk

CONTENTS

www.spaceanswers.com



TWEET US
@spaceanswers



POST ON FACEBOOK
/AllAboutSpaceMagazine



**SEND US
AN EMAIL**

space@spaceanswers.com

LAUNCH PAD

YOUR FIRST CONTACT
WITH THE UNIVERSE

06 Your photos of Comet NEOWISE, the discovery of a gigantic galactic structure that stretches billions of light years and NASA's latest update on getting humans back to the Moon



FEATURES

14 **The crash that made our Moon**

Understanding the intricacies of our lunar companion's formation could explain our existence

22 **Future tech Interstellar ramjet**

24 **The end of space and time**

To better understand the universe, we may need to kill off Einstein's famous idea

32 **Instant expert What is zodiacal light?**

34 **Interview Parker Solar Probe: two years on**

Dr Nour Raouafi reveals the Sun as its never been seen before and what's next for the solar space mission

38 **How big is Antares?**

The local red supergiant star has been mapped in extraordinary detail by radio telescopes

42 **What happens when we contact alien life?**

How we'll prepare the world for the biggest discovery in the history of humanity

50 **Shooting for the Moon**

How NASA trained Neil Armstrong and his crewmates to land on the lunar surface

56 **On board a top- secret space shuttle**

An X-37B has been sent into orbit for its sixth mystery mission. What has the ex-NASA spacecraft been up to?

64 **Ask Space**

Your questions answered by our space experts



**FREE LIMITED-EDITION
APOLLO 11 DIE-CAST MODEL**

TURN TO **PAGE 48**
FOR DETAILS





3 FREE eBOOKS WORTH £30!

55 Download **60 Second Science**, **History of NASA** and **Events that Changed the World** on your smartphone or tablet device



MADE ON

TOP- SECRET SPACE SHUTTLE



38 HOW BIG IS ANTARES?

56

THE END OF SPACE AND TIME?

24

STARGAZER

Your complete guide to the night sky

68 **What's in the sky?**

Even with NEOWISE dimming and the Perseids departing, there's still plenty to observe

72 **Month's planets**

Gaseous duo Jupiter and Saturn still make a stunning pair before they dip below the horizon

74 **Moon tour**

To the south of Plato are mountains worth exploring with a telescope

75 **Naked eye and binocular targets**

Time to meet some of the summer Milky Way's treasures

76 **Deep sky challenge**

Glittering star clusters, a dead star's corpse and a beautiful double star

78 **The Northern Hemisphere**

Aquarius and Pegasus grace the skies going into September

80 **Telescope review**

Is the Sky-Watcher Explorer-130PS the right telescope for you? Here's our full test

WIN!

MEADE INFINITY 90AZ

WORTH
£200!



13

COMET NEOWISE EDITION

NEOWISE blazes brightly over O'Brien's Castle

Photographer:
Cormac Coyne

This photo was taken from Inisheer, the smallest of the Aran Islands that sits in the middle of Galway Bay on the west coast of Ireland. Just after midnight on 11 July, photographer Cormac Coyne climbed up to one of the highest points on Inisheer that overlooks O'Brien's Castle. "When I was setting up above the castle, noctilucent clouds were just beginning to form," he said.

To capture NEOWISE, Coyne used a Canon EOS, coupled with a Canon 70-200mm f/2.8 Mark 3 lens. Despite being a naked-eye comet, Coyne also observed NEOWISE through binoculars. "I took the photos into Adobe Camera Raw, processed them and then saved them as a JPEG file," he added.



Strokes of celestial and artificial light

Photographer:
Björn Hoffmann

"In the early morning of 10 July I was able to capture some stunning images of Comet C/2020 F3 (NEOWISE) and noctilucent clouds in Stuttgart, Germany," said Björn Hoffman. "Together with the dark clouds, a beautiful contrast formed."

Hoffman stacked photos in software Sequator, followed by processing in Adobe Lightroom, Topaz DeNoise AI and Luminar Flex. By stacking images, it becomes possible to dive deep into the image and reveal fine detail.

The comet captured at Corfe's ruin

Photographer:
Kevin Ferriolo

Having seen other photographers' images of NEOWISE, Kevin Ferriolo ventured further afield on a clear night to capture the comet himself.

This image was taken on 11 July at 02:39 at Corfe Castle, Dorset, UK, using a Canon 450D with the Canon EF-S 55-250mm f/4-5.6 lens, shot at 55mm. The panoramic portion was shot with a ten-second exposure and ISO sensitivity of 1,600. The foreground was lit up by the moonlight, while minor adjustments were made in Adobe Lightroom to adjust shadows and contrast.





Close up of a space snowball

Photographer:
Stuart Hilliker

Stuart Hilliker captured these images in Angmering, West Sussex, UK, on 12 July 2020. "I used a William Optics Megrez 72 telescope, a Canon 700D camera and an AstroTrac camera mount," said Hilliker.

Eight minutes worth of useful data was captured over a two-hour period. Various exposure times and ISOs were used, with the most successful being at 15 seconds with an ISO of 1,600. The images were processed and refined using DeepSkyStacker and later, Adobe Photoshop.



'Partial supernova' blasts white dwarf star across the Milky Way

Words by Charles Q. Choi

A strange white dwarf star hurtling through the Milky Way may be the survivor of a 'partial supernova', a new study finds.

White dwarfs are the cool, dim Earth-sized cores of dead stars that are left behind after average-sized stars have exhausted their fuel and shed their outer layers. Our Sun will one day become a white dwarf, as will more than 90 per cent of the stars in the Milky Way.

Scientists zeroed in on the white dwarf SDSS J1240+6710, located about 1,430 light years from Earth. Discovered in 2015, prior work found this white dwarf had an unusual atmosphere that seemed to possess neither hydrogen or helium, but instead was composed of a weird mix of oxygen, neon, magnesium and silicon. The Hubble Space Telescope was used to take a closer look at the white dwarf, and it identified carbon, sodium and aluminium in the object's

atmosphere. This mix sets this white dwarf apart from any other previously known.

In the research the scientists also found that the white dwarf was travelling at about 900,000 kilometres per hour (560,000 miles per hour) in the opposite direction of the way the galaxy is rotating. Moreover it had an especially low mass for a white dwarf - only about 40 per cent the mass of our Sun. "When we found this unusual white dwarf was really low in mass and moving really fast, that really triggered my curiosity into what happened to it in its past," said Boris Gänsicke, an astrophysicist at the University of Warwick, UK.

What might explain all these strange details about this white dwarf? The researchers think that a thermonuclear explosion didn't completely destroy the white dwarf, but rather a 'partial supernova' blasted what remained of the object across the Milky Way.

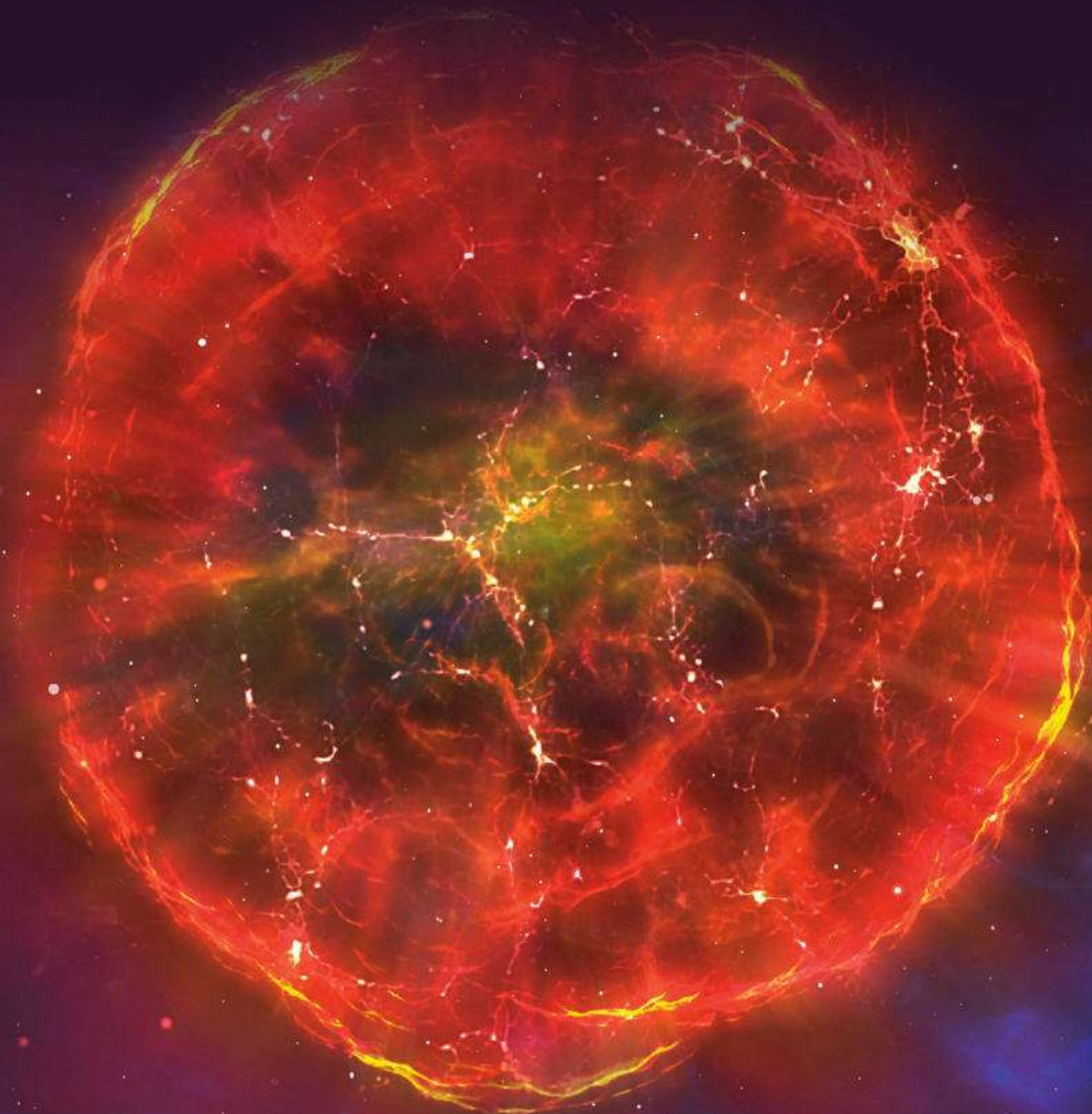
In the case of SDSS J1240+6710, the scientists noted that the elements seen in the white dwarf's atmosphere could have all been produced in the first thermonuclear reactions of a supernova. However, there is a clear absence of what is known as the iron group of elements - iron, nickel, chromium and manganese.

"That's what makes this white dwarf unique - it did undergo nuclear burning, but stopped before it got to iron," said Gänsicke. "When it had its supernova event, it was likely just brief, maybe a couple of hours."

The explosion would have blasted SDSS J1240+6710 away from its companion, ripping matter off the small white dwarf and hurling it through deep space at the speed at which it orbited its partner.

The scenario - the researchers said - would help to explain the white dwarf's speed, puny size and bizarre atmosphere.

The strange white dwarf doesn't contain any iron like most post-supernova stars do



Strange ancient 'failed stars' found by citizen scientists

Words by Doris Elin Urrutia

Citizen scientists recently helped direct astronomers to a pair of objects that straddle the line between planets and stars. These newly spotted substellar objects are brown dwarfs, which share many elements in common with stars. However, unlike stars these gaseous bodies don't have enough mass to start nuclear fusion in their core, so they resemble planets more than stars.

These newfound brown dwarfs have very unusual compositions. They are the most planet-like brown dwarfs to be observed in the Milky Way's oldest populations of stars. They also might help researchers learn more about planets outside the Solar System.

The citizen scientists who spotted both objects were part of the ongoing NASA-funded Backyard Worlds: Planet 9 project. They were looking through spacecraft data from NASA's WISE and NEOWISE missions; both missions are chapters in the life of a single spacecraft called the Wide-field

Infrared Survey Explorer, and the objects that the collaboration recently found, now called WISE 1810 and WISE 0414, are weird.

When scientists studied them, they were surprised to see that these two brown dwarfs have very little iron compared to what's usually observed in brown dwarfs. This is a telltale sign that they are ancient, with each estimated to be about 10 billion years old. Both dwarfs have a mass of about 75 times the mass of Jupiter.

If these brown dwarfs formed with low levels of metal, so might ancient exoplanets. This could be a reason to search for old metal-poor exoplanets or alien worlds that orbit ancient metal-poor stars. Further research into this brown dwarf population could answer questions about how dependent the planet formation process is on the presence of metals. NASA representatives said Backyard Worlds: Planet 9 has contributed to more than 1,600 brown dwarf discoveries.



©NASA/JPL-Caltech

Gigantic structure stretching 1.37 billion light years across discovered

Words by Adam Mann

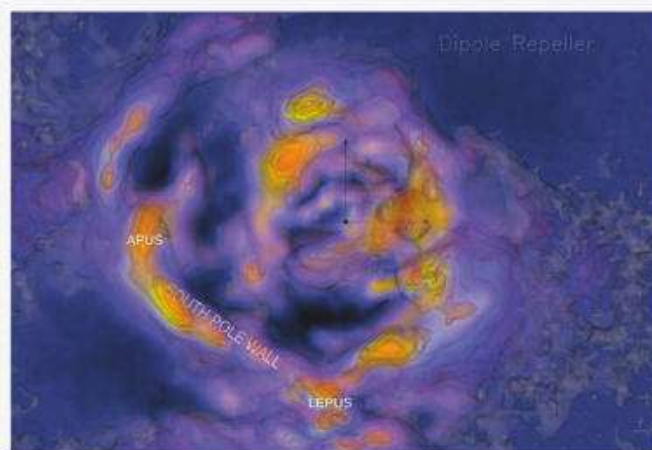
Spectacular 3D maps of the universe have revealed one of the biggest cosmic structures ever found - an almost-inconceivable wall stretching 1.37 billion light years across that contains hundreds of thousands of galaxies. The South Pole Wall, as it's been dubbed, has been hiding in plain sight, remaining undetected until now because large parts of it sit half a billion light years away behind the bright Milky Way galaxy. The South Pole Wall rivals in size the Sloan Great Wall, the sixth-largest cosmic structure discovered. One light year is roughly nine trillion kilometres (six trillion miles), so this cosmic structure is mind-bendingly humongous.

Astronomers have long noticed that galaxies are not scattered randomly throughout the universe, but rather clump together in what's known as the cosmic web, enormous strands of hydrogen gas in which galaxies are strung like pearls on a necklace that surround gigantic and largely empty voids.

Previous cosmographic work has charted the extent of other galactic assemblies, such as the current structural record holder, the Hercules-

Corona Borealis Great Wall, which spans 10 billion light years - more than a tenth the size of the visible universe.

The resulting map of the South Pole Wall shows a mind-boggling bubble of material more or less centred on the southernmost point of the sky, with a great sweeping wing extending north on one side in the direction of the constellation Cetus and another stubbier arm opposite it in the direction of the constellation Apus.



© D. Pomarede, R. B. Tully, R. Graziani, H. Courtois, Y. Hoffman, J. Lezmy

HOW IT WORKS

subscription offer

FROM £2.38 PER ISSUE!

ENJOY INSTANT READING

Our digital editions come with the same features included in the print edition!



This offer is **only** available via our online shop
www.myfavouritemagazines.co.uk
 /hiwd/DIGCSP20



© CSIRO

Four mysterious objects spotted in deep space

Words by Mara Johnson-Groh

There's something unusual lurking out in the depths of space: astronomers have discovered four faint objects that at radio wavelengths are highly circular and brighter along their edges. And they're unlike any class of astronomical object ever seen before. The objects, which look like distant ring-shaped islands, have been dubbed odd radio circles (ORCs) for their shape and overall peculiarity.

Astronomers don't yet know exactly how far away these ORCs are, but they could be linked to distant galaxies. All the objects were found away from the Milky Way's galactic plane and are around one arcminute across - as a comparison, the Moon's diameter is 31 arcminutes.

The astronomers offered several possible explanations for the phenomena, but none quite

fits the bill for all four new ORCs. After ruling out objects like supernovae, star-forming galaxies, planetary nebulae and gravitational lensing - a magnifying effect caused by the bending of space-time by nearby massive objects - among other things, the astronomers speculate that the objects could be shock waves from some extragalactic event or possibly activity from a radio galaxy.

"[The objects] may well point to a new phenomenon that we haven't really probed yet," said Kristine Spekkens, astronomer at the Royal Military College of Canada and Queen's University, who was not involved with the new research. "It may also be that these are an extension of a previously known class of objects that we haven't been able to explore."

Above: It's still unknown what could be causing the radio circles

NASA human spaceflight chief makes no guarantees on return to Moon

Words by Hanneke Weitering

Putting astronauts back on the Moon by 2024 will be no small feat, and NASA's new human spaceflight chief Kathy Lueders has been careful not to make any promises. "I don't have a crystal ball," Lueders said when asked about the feasibility of a 2024 Moon landing. "I wish I knew that answer. That'd make my job a lot easier. We're going to try."

Lueders, who recently became the associate administrator for NASA's Human Exploration and Operations Mission Directorate after Doug Loverro's abrupt resignation, was a bit more pragmatic about the timeline of NASA's Artemis program than her predecessor. While Lueders seems cautiously optimistic about getting astronauts to the Moon by 2024, Loverro was confident and unwavering in his assertion that NASA would make the deadline. At a NASA town hall in

December Loverro even said that "it is going to be easy to make this happen".

Before Lueders became the head of human spaceflight at NASA she served as the manager of NASA's Commercial Crew Program. Those missions have faced years of delays and other challenges. When NASA created its Commercial Crew Program in 2010, the agency planned to have its astronauts regularly riding private vessels to and from the space station by 2015. Now, five years later, the first commercial crew mission has only just arrived at the orbiting lab.

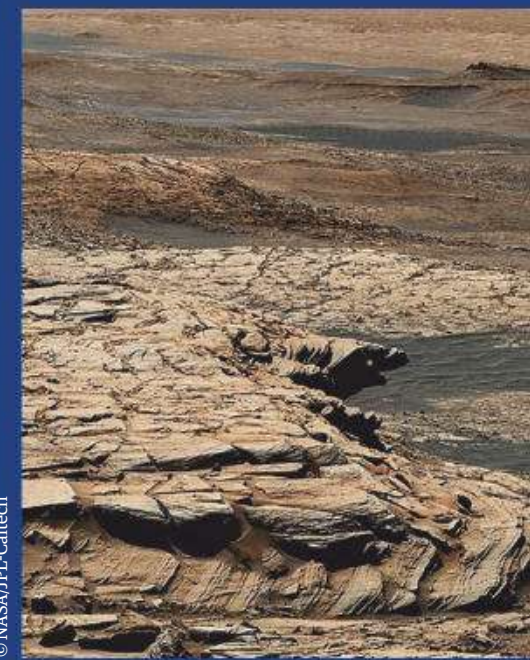
"It's very important to have an aggressive goal," Lueders said in a teleconference on 18 June. "We had an aggressive goal in Commercial Crew, and I think that aggressive goal ensured that we were able to accomplish things as quickly as we could."

Left: Aeolis Mons lies in Gale crater, forming its central peak

Right: Lueders is the first woman to head human spaceflight at NASA



© NASA



© NASA/JPL-Caltech

WIN



WORTH
£200

MEADE INFINITY 90AZ TELESCOPE

Become entranced with stargazing as this refractor reveals the cosmos

This achromatic refractor is the second-largest telescope in Meade's Infinity family, and we've got one waiting to be won thanks to Hama (UK) Ltd. Flaunting a 90-millimetre (3.5-inch) aperture and 600-millimetre (24-inch) focal length to provide a focal ratio of f/6.7, this instrument is excellent for resolving bright celestial objects - such as the Moon, planets or stars - with amazing clarity and contrast. The optical system and setup also comes in handy for basic astrophotography. Built for terrestrial viewing as an added bonus, the Infinity 90AZ is also perfect for nature observations.

Accessories are also included, with a red-dot viewfinder, a Barlow lens (2x), three eyepieces and an accessory tray and AutoStar® Suite Astronomer Edition Software, perfect for seamless guiding around the night sky.



To be in with a chance of winning, answer this question:

**What is the name of the largest volcano
in the Solar System?**

A: Olympus Mons (Mars) **B:** Mauna Loa (Earth) **C:** Maat Mons (Venus)

Competition ends on 10 September 2020

Enter online at **spaceanswers.com** or by post to
All About Space competitions, Quay House, The Ambury, Bath, BA1 1UA

Visit the website for full terms and conditions at **futureplc.com/terms-conditions/**



What made our Moon?

THE CRASH THAT MADE

OUR MOON

Understanding how our lunar companion was formed might just explain how we came to be here

Reported by Colin Stuart

It's the brightest thing in our night sky. Over the course of history it has been revered as a god, trampled across by 12 men and immortalised in poetry. The Moon is our steadfast companion, our only natural satellite as we endlessly orbit the Sun. Yet for an object that has received such scrutiny, arguments rage about where exactly the Moon came from. A suitable explanation needs to take into account what is perhaps the Moon's greatest oddity: its size. It is the fifth-largest moon in the Solar System, trumping most of the satellites of our much bigger planetary neighbours. If you compare the size of moons to the size of their host planet, ours comes out at the very top. Many of the smaller moons of the Solar System are thought to be captured worlds - bodies that wandered too close to a planet before getting snared in its gravitational pull. Given the size of our Moon, it's hard to imagine that's how it ended up circling Earth.

As far back as 1878, George Darwin - the astronomer son of famous naturalist Charles

What made our Moon?



Left: Astronaut Harrison Schmitt is seen covered in lunar dirt while collecting samples during the Apollo 17 mission

Darwin - instead proposed that Earth and the Moon were once one body and that the latter formed from material thrown off the spinning Earth. This, he said, would explain why the Moon was moving a little further away from us each year. Supporters of this idea even pointed to the lack of land in the Pacific Ocean - which stretches across half of our planet - as the birthplace of the Moon. However, scientists later realised that any force capable of dislodging such a large amount of Earthly material would likely have destroyed the rest of our planet at the same time.

Attention turned instead to the idea of a giant impact - one that occurred 4.5 billion years ago

when a young Earth was still forming. It must have been this early because the rocks brought back from the Moon are that old. Astronomers have long believed that the Solar System had a tempestuous infancy, throwing around huge lumps of rock and metal before eventually calming down. What if one of these objects - perhaps one the size of Mars - hit the young Earth, with the Moon forming out of the hot, spinning debris?

On the face of it this idea makes a lot of sense. We know from the dark patches on the lunar surface that parts of the Moon were once molten. The Moon also has a pretty small iron core - much smaller than Earth's - and it is less dense than Earth. This also fits, because during an impact the lightest material would have been thrown the furthest, leaving the heavier stuff here on Earth. Astronomers have a name for this proposed Mars-sized impactor: Theia, named after the Titan who gave birth to the Moon goddess Selene in Greek mythology. Computer modelling has been used to try and figure out what this impact must have been like in order for it to form the modern Moon.

“IF THE MOON WAS MOSTLY FORMED FROM A SMASHED-APART THEIA DURING A GLANCING BLOW WITH EARTH, IT SHOULD HAVE ITS OWN UNIQUE OXYGEN ISOTOPE SIGNATURE. YET INSTEAD IT MATCHES EARTH’S EXACTLY”

How the Moon *wasn't* made



It was flung off a rapidly spinning Earth

What is it?

An idea which was popular for decades was that the material which makes up the Moon was once part of Earth. It suggested the Moon separated from Earth while it was semi-molten and spinning rapidly, and many saw the Pacific Ocean as a void created by the departing material. Darwin backed up the idea with solid and accurate calculations.

Why it's wrong

By the 1930s calculations showed that Earth would have had to spin at an inconceivable rate to throw off enough material to form the Moon.



It was made elsewhere and captured by Earth

What is it?

Many of the moons in our Solar System are thought to be captured objects - Phobos and Deimos around Mars are good examples. It isn't inconceivable that Earth could have captured the Moon, as this would explain why the Moon and Earth appear to have different densities.

Why it's wrong

For Earth to capture a large Moon, both objects would have to travel slowly - a collision was more probable. It's also unlikely that Earth's gravity would've been able to hold the Moon for so long.



It was formed at the same time as Earth

What is it?

The co-accretion idea is that Earth and the Moon formed together in the early Solar System from the debris around the newborn Sun. Support came from observations of double stars. If two distinct stars could form out of a nebula, then it seemed at least possible that two worlds might coalesce side by side in orbit around a single star.

Why it's wrong

While the oxygen isotopes may be the same, the densities of Earth and the Moon and the amounts of iron on each are different.

How the Moon was made

1 Theia approaches Earth

A Mars-sized object is on an unalterable collision course with the early Earth.



2 Earth gets hit

The impactor hits Earth in a head-on collision, vaporising both Theia and Earth's mantle.



3 Material is thrown out

The vaporised material from both bodies mixes and is thrown outwards by the huge impact.



4 Debris gathers

Smaller objects begin to condense out of the vapour while continuing to orbit around Earth.



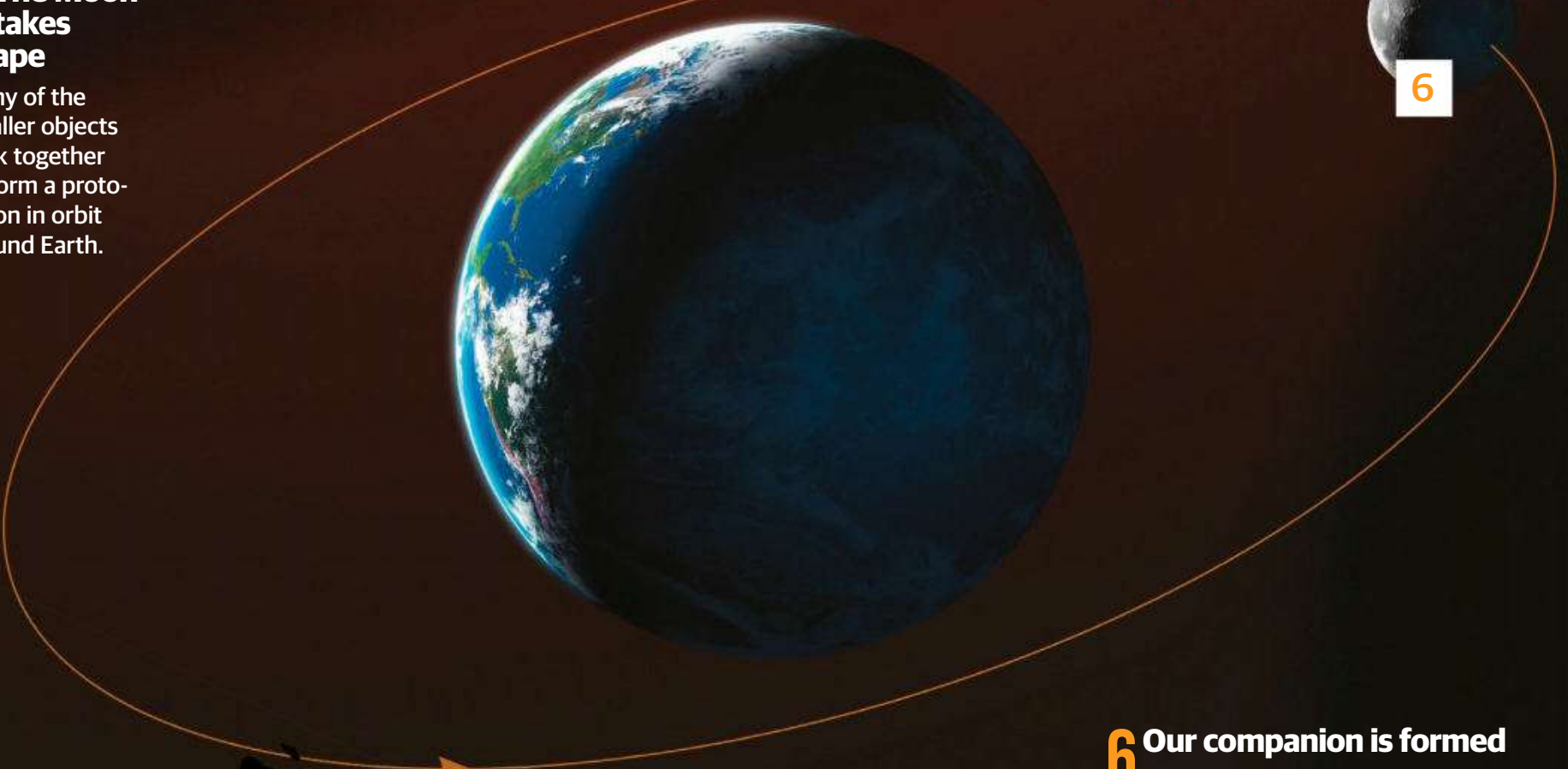
5 The Moon takes shape

Many of the smaller objects stick together to form a proto-Moon in orbit around Earth.



6 Our companion is formed

Eventually all the pieces come together to form the basis of the Moon that we see today.



Theia by numbers

6,000KM

The width of the Theia impactor, which is about the same size as Mars

1974

The year the giant-impact hypothesis was first presented at a conference

60-80°

The axial tilt of Earth after Theia collided with the planet

4.5 BILLION

The number of years ago it is thought Theia collided with Earth to form the Moon

45°

Although new research suggests a head-on collision, the old picture had a 45-degree glancing blow

© Science Photo Library

Traditionally the best fit seems to come from a glancing blow - Theia clipping Earth at an angle of about 45 degrees - and at a relatively slow speed. The debris from the impact, mostly formed from the leftover remnants of Theia, would have formed a ring around Earth, which then coalesced into the Moon. But recent analysis of Moon rocks returned to Earth during the Apollo missions appears to throw a spanner in the works.

It is all to do with isotopes. What sets different chemical elements apart is the number of protons present in the nucleus of their atoms. Oxygen, for example, always has eight. Add another proton and you get an entirely different element - fluorine in this case. But several versions of the same element can exist, each with the same number of protons

but a differing number of neutrons. Scientists call these different flavours of the same element 'isotopes'. Oxygen, for example, has three stable isotopes, with eight, nine or ten neutrons.

When it comes to planetary geology, the relative amounts of each of these isotopes present on a celestial object are a key measurement, a bit like a fingerprint. "Each body in the Solar System has a unique oxygen isotope signature," says Dr Kun Wang, assistant professor of Earth and planetary sciences at Washington University in St Louis. And therein lies the problem. Analysis of the Apollo samples shows that Moon rocks have exactly the same oxygen isotope signature as Earth. If the Moon was mostly formed from a smashed-apart Theia during a glancing blow with Earth, it should

have its own unique oxygen isotope signature. Yet instead it matches Earth's signature exactly.

Scientists first discovered this as far back as 2001, but many believed that this apparent similarity was just an artefact of the precision of the experiments - that one day more accurate analysis would show there to be a tiny difference after all. However, the latest research published found that even with much more precise measurements, the oxygen isotope signature is still identical. Therefore the Moon did not form from Theia alone.

Wang believes this points to a much more violent collision, one which melted the outer layers of both Earth and Theia. This material then mixed together to form a vapour - a cloud of material - stretching from our planet out to 500 Earth radii. The Moon

2000

The year that the name Theia was proposed by English geochemist Alex Halliday



then condensed from this cloud, explaining why both bodies now have the same oxygen isotopes. "Once they mix together it doesn't matter what the oxygen isotopes of the two bodies were before," says Wang. But if the notion of a more catastrophic impact is to be accepted, it needs more than one strand of supporting evidence, so that is exactly what Wang set out to find.

He analysed seven different Moon rock samples from multiple Apollo missions, along with samples of Earth rocks, measuring the different abundances of isotopes of potassium using a technique ten-times more accurate than previously possible. In October 2016, along with his colleague Stein Jacobsen from Harvard University, he published his results. He found that the Moon rocks had a greater abundance of one particular potassium isotope at the level of 0.4 parts per 1,000 more than Earth. "Potassium is a lot more volatile than oxygen, meaning it is more likely to vaporise and be mobile after the collision," says Helen Williams, an Earth scientist at the University of Cambridge. The potassium was therefore much more likely to end up far away from Earth and become incorporated as part of the Moon. But for potassium to be vaporised in the first place, the collision must have vaporised both Theia and much of Earth's surface. To Wang that has all the hallmarks of a head-on collision rather than a glancing blow.

"THE MOON ROCKS HAD A GREATER ABUNDANCE OF ONE PARTICULAR POTASSIUM ISOTOPE AT THE LEVEL OF 0.4 PARTS PER 1,000 MORE THAN EARTH"

Left: Mars-sized Theia approaches the still-molten Earth before the collision

Moon rock analysis



The age of the Moon

Analysis of lunar rocks suggests the Moon is almost as old as Earth, meaning the collision happened within Earth's first 100 million years.



Matching oxygen isotopes

The relative abundances of the three stable isotopes of oxygen are the same on Earth and the Moon, suggesting a common origin.



No sign of water

The Moon rocks show no signs of past interaction with water. All the geology can be explained as rocks being under pressure.



Differing potassium isotopes

There is slightly more of one particular potassium isotope on the Moon, pointing to it being vaporised during a head-on collision.



Source: Wikipedia Commons © Bryce Edwards



Left: Wearing special germ-free clothing, Dr Robert Gilruth (right) inspects lunar samples from the Apollo 17 mission

© NASA

What made our Moon?

But even if he is correct there are still some outstanding Moon mysteries in need of explanation - none more so than the unusual tilt of the Moon's orbit around Earth. The Moon would have initially formed in an orbit matching the orientation of Earth's equator. As it moved further from our planet, the gravitational pull of the Sun would have forced it into line with the orbits of the other planets - a plane known as the 'ecliptic'. Yet today's Moon orbits at an angle of five degrees to the ecliptic. "That might not sound like much, but all the other big moons of the Solar System are inclined at less than a degree to their planets - so the Moon really stands out," says Douglas Hamilton, professor of astronomy at the University of Maryland. A team led by Hamilton has recently attempted to explain this strange anomaly. They ran many computer simulations of the giant impact, with slightly different parameters each time. The one that gave the closest match to the Moon's

current orbit suggests Theia's impact was a lot more calamitous for our planet than previous models have suggested.

The almighty wallop from Theia would have sent Earth spinning much faster. More than twice as fast, in fact, as other previous models have suggested. What's more, Earth would have been knocked over almost on its side, with its axis tilted somewhere between 60 and 80 degrees to the ecliptic - today it is only tilted by 23.4 degrees.

This high inclination affected the Moon as it retreated from Earth, forcing it into an orbit tilted at an angle of around 30 degrees to the ecliptic. "It then settled down to five degrees over the last



4.5 billion years," says Hamilton. At the same time Earth's axis started to straighten up to its present position. It just goes to show that our ideas about the formation of the Moon are still very much in flux.

Quite how we came to have such a large Moon on an inclined orbit is a puzzle still occupying teams of astronomers around the world. But it seems we are getting closer.

And that's very important, because discovering the Moon's history is a key step in understanding how likely such events are in the wider universe. This in turn might help us answer a much bigger question: whether we are alone in the universe. That's because many scientists have speculated that the churning of the oceans by a Moon that was much closer to Earth than it is today could have played a key role in the early development of life on Earth. Its gravitational pull also stabilises Earth's axis, keeping our seasons steady and reliable every year. This flurry of recent research has put us one step closer to understanding how our Moon came to be, and may one day help us understand our place in the universe.

"EARTH WOULD HAVE BEEN KNOCKED OVER ALMOST ON ITS SIDE, WITH ITS AXIS TILTED SOMEWHERE BETWEEN 60 AND 80 DEGREES TO THE ECLIPTIC"



Above: Unlike Mars' moon Deimos, our Moon wasn't captured as it passed by our planet

Left: We are still not certain on how the Moon ended up in orbit around Earth

Lunar make-up

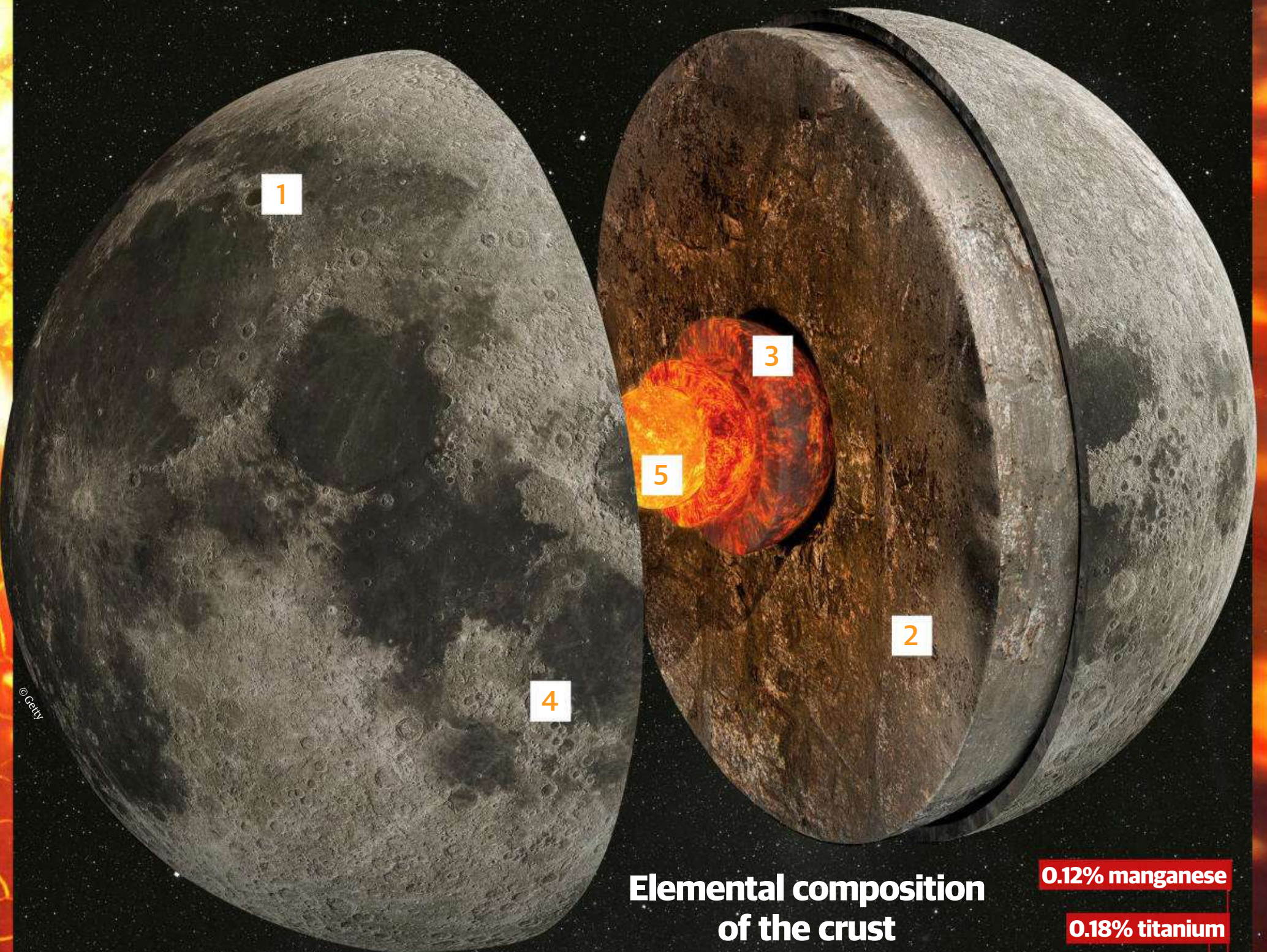
1 Crust

2 Lithospheric mantle

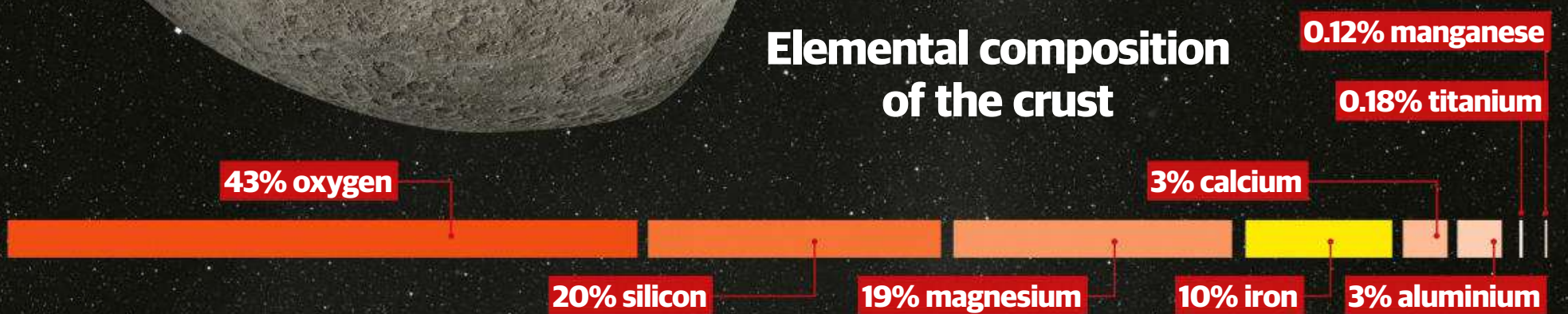
3 Partially molten asthenosphere

4 Maria (lunar seas)

5 Core



Elemental composition of the crust



Moon core

Fe
IRON

Ni
NICKEL

Moon mantle

ORTHOPYROXENE
Opx

CLINOPYROXENE
Cpx

OLIVINE

Moon crust

O
OXYGEN

Si
SILICON

Mg
MAGNESIUM

Fe
IRON

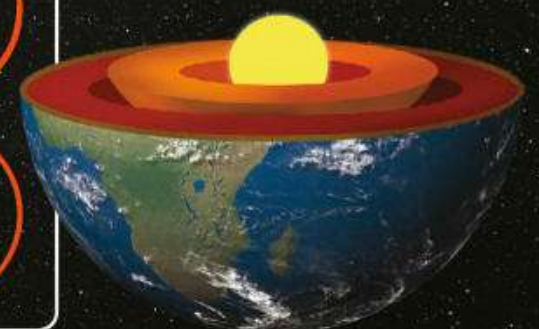
Ca
CALCIUM

Al
ALUMINIUM

Also found in Earth's

○ Crust ○ Mantle

○ Core



INTERSTELLAR RAMJET

Travelling between stars takes a lot of energy, but we might be able to pick some up on our way through space

The trouble with rockets is that you have to pack everything before you go. While earthly modes of transport all work within their environment, shooting around air or water or rolling along a surface, rockets must carry whatever they are going to shoot out the back - reactive mass - with them. This effect is exacerbated because the reactive mass you'll be using at the end of the flight is just dead weight at the start. So you need even more mass and energy at the start just to lift the mass and energy you will need later on. This is why it is so challenging and expensive to get into space. Rockets are so big compared to the payloads they launch because they need to be more than 90 per cent full of propellants at take off.

Once you're in space you have more options: craft don't need to be aerodynamic and the engines don't need to support a craft against gravity, so a small thrust over a long time is equivalent to a large one over a short time. However, if we want the space travel of fiction, to voyage across the stars to find other planets and life, the challenge gets even greater.

Proxima Centauri, the nearest star beyond the Sun, is 4.2 light years away, so traditional rockets would take thousands of years to get there. Worse still, if we are to approach light speed to minimise the travel time we have to drag even

1 Fusion reactor

The hydrogen would be used to fuel a fusion reactor which would fuse hydrogen into helium, releasing a tremendous amount of heat energy.

2 Exhaust

The ramjet produces forward thrust by directing the ions produced from fusion out of the exhaust at a high velocity.

3 Fissionless

Current nuclear technology uses fission, where heavy atoms like uranium are split to release energy. But this does leave behind long-lived nuclear waste.

4 Nuclear fusion

The ramjet uses nuclear fusion. This releases energy by combining light atoms into heavier ones. It is cleaner and more powerful, but more difficult to achieve.

7

7 Magnetic scoop

The ramjet needs a magnetic scoop because the hydrogen atoms are so spread out. The scoop has to be many kilometres across to collect sufficient fuel.

8

8 Interstellar space

Though we think of space as empty, there is quite a lot of gas and dust between the stars.

6 Thermal and radiation shield

Fusion does not produce the same radioactive waste as fission, but when running on hydrogen the crew would need protection from neutrons and the exhaust heat.

5 Fuel tanks

The spacecraft needs to be able to run the reactor to power its systems, including the scoop, from a standstill. It would probably use deuterium, an easier fuel to fuse.

more propellant up to super-high speeds. As a result the Daedalus fusion-powered interstellar probe concept would stand nearly as tall as the Empire State Building and weigh 54,000 tonnes – 50,000 tonnes being propellant. But space isn't as empty as it appears, so what if we could make use of the resources already out there?

In 1960 nuclear physicist Robert Bussard proposed such a system: the Bussard ramjet. A ramjet is an engine that uses its forward speed to ram air into the engine, instead of the fan blades seen on jet engines. With the Bussard ramjet a craft would be initially set moving by a fusion-powered rocket using internal fuel, and then it would generate a huge funnel-shaped magnetic field. This could collect the free hydrogen molecules that float around in interstellar space and duct them back to the spaceship. Once collected the hydrogen molecules could be used as fuel for a fusion-powered rocket.

Nuclear fusion is the most powerful reaction we have available from ordinary matter. Current

nuclear power stations use nuclear fission where energy is released by splitting heavy atoms, but in nuclear fusion energy is released by combining light atoms, which is cleaner and more powerful. The hydrogen molecules would be fused together, producing a hot jet of helium gas to push the spacecraft along while it collects more fuel.

There are challenges of course: the scoop would have to gather one trillion cubic kilometres (240 billion cubic miles) of space to pick up one kilogram (2.2 pounds) of hydrogen. Scooping up the hydrogen may create more drag than the engine can overcome, and hydrogen itself is not easy to fuse. Some studies have suggested it might be better to just use the interstellar hydrogen as a reactive mass, heated up by a separately fuelled fusion reactor.

Though the Bussard ramjet is still a theoretical concept, it has already had a cultural impact as the 'Bussard Ramscoop' on the front of the Starship Enterprise in *Star Trek*.

IS THIS THE END OF SPACE AND TIME?

To better understand the universe we may need to
kill off Einstein's long-standing theory

As in history, revolutions are the lifeblood of science. Bubbling undercurrents of disquiet boil over until a new regime emerges to seize power. Then attention turns to toppling the new ruler. The king is dead, long live the king. This has happened many times in the history of physics and astronomy. First we thought the Earth was at the centre of the Solar System - an idea that stood for over a thousand years. Then Copernicus stuck his neck out to say we are just another planet orbiting the Sun. Despite much initial opposition, the old geocentric picture buckled under the weight of evidence from the newly invented telescope.

Then Newton came along to explain that gravity is why the planets orbit the Sun. He said all objects with mass have a gravitational attraction towards each other. According to his ideas we orbit the Sun because it is pulling on us, and the Moon orbits Earth because we are pulling on it. Newton ruled for two-and-a-half centuries before Albert Einstein turned up in 1915 to usurp him with his general theory of relativity. This new picture neatly explained inconsistencies in Mercury's orbit, and was famously confirmed by observations of a solar eclipse off the coast of Africa in 1919.

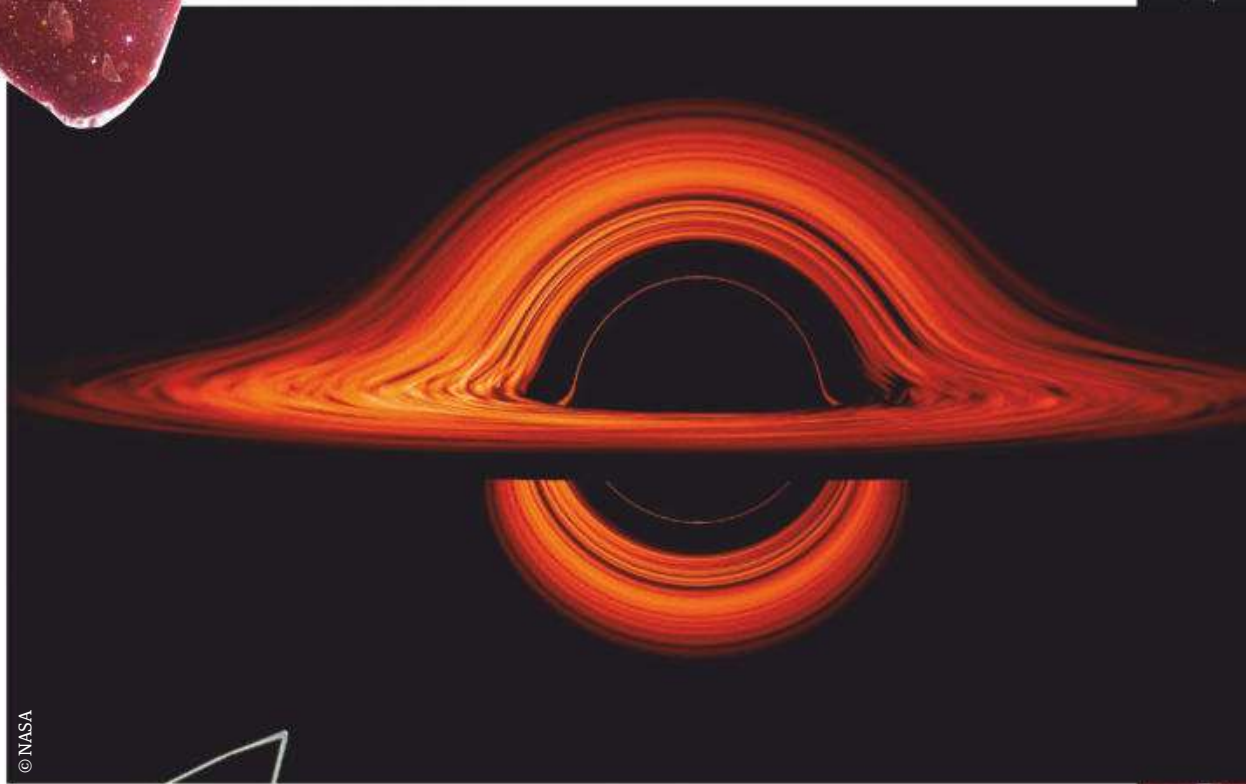
Instead of a pull, Einstein saw gravity as the result of curved space. He said that all objects in the universe sit in a smooth, four-dimensional fabric called space-time. Massive objects such as the Sun warp the space-time around them, and so Earth's orbit is simply the result of our planet following this curvature. To us that looks like a Newtonian gravitational pull. This space-time picture has now been on the throne for over 100 years and has so far vanquished all pretenders to its crown. The discovery of gravitational waves in 2015 was a decisive victory, but like its predecessors, it too might be about to fall. That's because it is fundamentally incompatible with quantum theory.

The quantum world is notoriously weird. Single particles can be in two places at once, for example. Only by making an observation do we force it to 'choose'. Before an observation we can only assign probabilities to the likely outcomes. In the 1930s Erwin Schrödinger devised a famous way to expose how perverse this idea is. He imagined a cat in a sealed box accompanied by a vial of poison attached to a hammer. The hammer is hooked up to a device that measures the quantum state of a particle. Whether or not the hammer smashes the vial and kills the

cat hinges on that measurement, but quantum physics says that until such a measurement is made the particle is simultaneously in both states, which means the vial is both broken and unbroken and the cat is alive and dead.

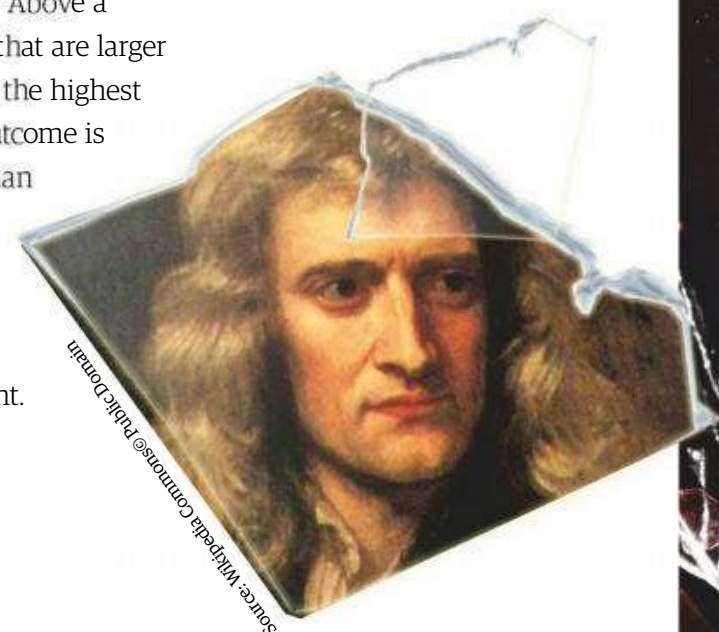
Such a picture cannot be reconciled with a smooth, continuous fabric of space-time. "A gravitational field cannot be in two places at once," says Sabine Hossenfelder, a theoretical physicist at the Frankfurt Institute for Advanced Studies. According to Einstein, space-time is warped by matter and energy, but quantum physics says matter and energy exist in multiple states simultaneously - they can be both here and over there. "So where is the gravitational field?" asks Hossenfelder. "Nobody has an answer to that question. It's kind of embarrassing," she says.

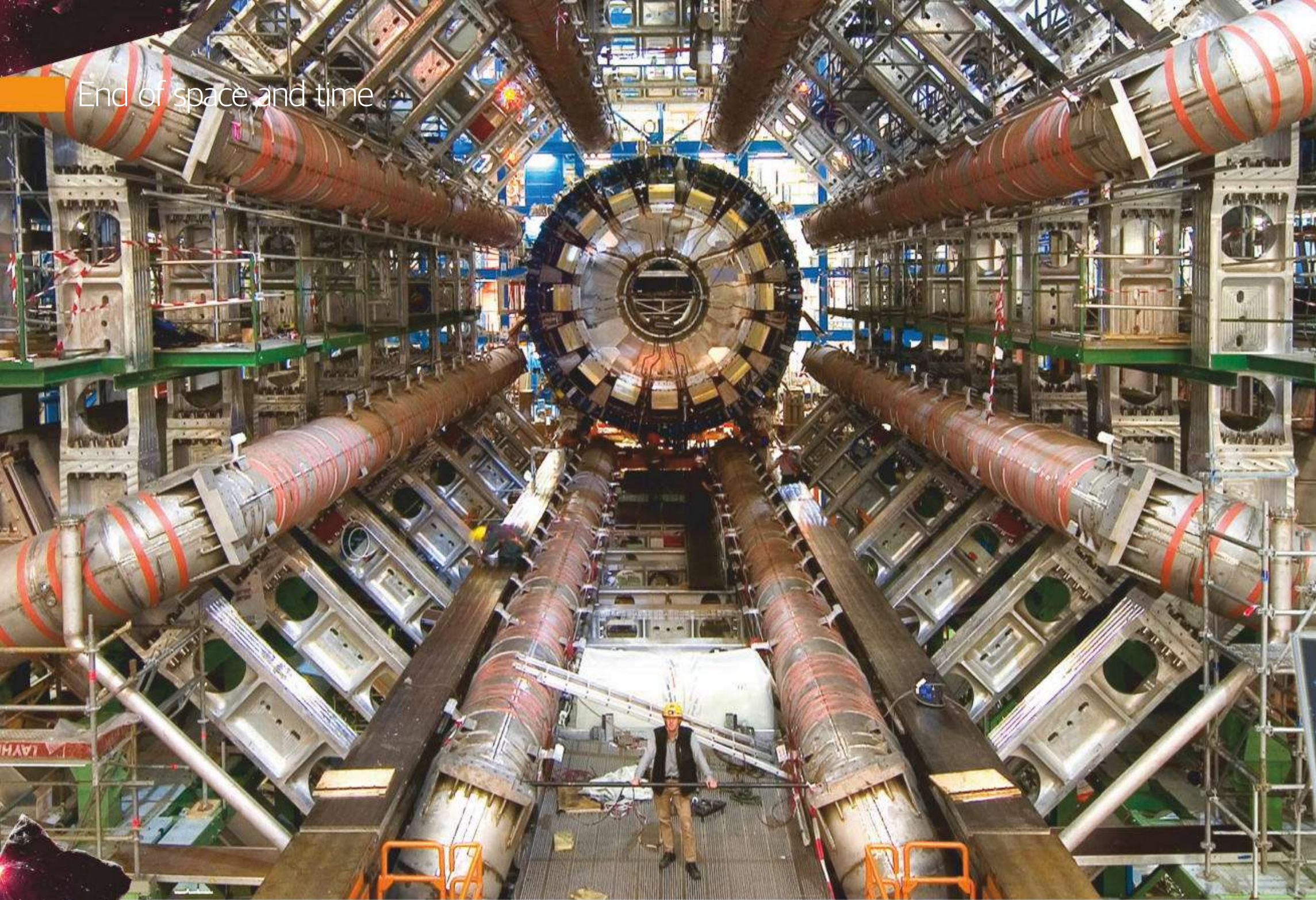
Try and use general relativity and quantum theory together and it doesn't work. "Above a certain energy you get probabilities that are larger than one," says Hossenfelder. One is the highest probability possible - it means an outcome is certain. You can't be more certain than certain. Equally, calculations sometimes give you the answer infinity, which has no real physical meaning. The two theories are therefore mathematically inconsistent. So, like many monarchs throughout



Above: Black holes bend space and time with their great masses

Below: Newton came up with his ideas on gravity after seeing an apple fall





Above: You'd need a machine 1,000 trillion-times more powerful than the LHC to probe the Planck scale

Right: Einstein dispensed with the Newtonian picture of gravity as a force, replacing it with space-time

history, physicists are seeking a marriage between rival factions to secure peace. They're searching for a theory of quantum gravity - the ultimate diplomatic exercise in getting these two rivals to share the throne. This has seen theorists turn to some outlandish possibilities.

Arguably the most famous is string theory. It's the idea that subatomic particles such as electrons and quarks are made from tiny vibrating strings. Just as you can play strings on a musical instrument to create different notes, string theorists argue that different combinations of strings create different particles. The attraction of the theory is that it can reconcile general relativity and quantum physics, at least on paper. However, to pull that particular rabbit out of the hat, the strings have to vibrate across eleven dimensions - seven more than the four in Einstein's space-time fabric. As yet there is no experimental evidence that these extra dimensions really exist. "It might be interesting mathematics, but whether it describes the space-time in which we live, we don't really know until there is an experiment," says Jorma Louko from the University of Nottingham.

Other physicists have turned to an alternative called loop quantum gravity (LQG). They can get

"IF WE UNDERSTAND THE QUANTUM STRUCTURE OF SPACE-TIME BETTER, THAT WILL HAVE AN IMPACT ON FUTURE TECHNOLOGIES"

SABINE HOSSENFELDER

the two theories to play nicely if they do away with one of the central tenets of general relativity: that space-time is a smooth, continuous fabric. Instead, they argue, space-time is made up of a series of interwoven loops - it has structure at the smallest scales. This is a bit like a length of cloth. At first glance it looks like one smooth fabric. Look closely, however, and you'll see it is really made of a network of stitches. Alternatively, think of it like a photograph on a computer screen: zoom in and you'll see it is really made of individual pixels.

The trouble is that when LQG physicists say small, they mean really small. These defects in space-time would only be apparent on the level of the Planck scale - around a trillionth of a trillionth of a metre. That's so tiny that there would be more loops in a cubic centimetre of space





© CERN

Below:
Einstein's work
struggles to
explain how
two entangled
particles
seemingly
communicate
faster than the
speed of light



than cubic centimetres in the entire observable universe. "If space-time only differs on the Planck scale then this would be difficult to test in any particle accelerator," says Louko. You'd need an atom smasher 1,000 trillion-times more powerful than the Large Hadron Collider (LHC) at CERN. How can you detect space-time defects that small? The answer is to look across a large area of space.

Light arriving here from the furthest reaches of the universe has travelled through billions of light years of space-time along the way. While the effect of each space-time defect would be tiny, over those distances interactions with multiple defects might well add up to a potentially observable effect. For the last decade astronomers have been using light from far-off gamma-ray bursts to look for evidence. These cosmic flashes are the result of massive stars collapsing at the ends of their lives, and there is something about these distant detonations we currently cannot explain. "Their spectrum has a systematic distortion to it," says Hossenfelder. But no one knows if that is something that happens on the way here or if it's something to do with the source of the bursts themselves. The jury is still out.

To make progress we might have to go a step further than saying space-time isn't the smooth,

WHY CAN'T RELATIVITY AND QUANTUM MECHANICS GET ALONG?

QUANTUM MECHANICS

Particles are waves and waves are particles

This wave-particle duality is central to quantum physics. Light can be thought of as being made of particles called photons, or as a propagating electromagnetic wave.

All properties are 'quantised'

Values in quantum physics are a bit like shoes – they only come in set sizes. Physicists call these 'quanta'. An electron, for example, can only orbit the atomic nucleus in a limited number of configurations.

Objects exist in many states at once

Physicists say electrons exist in a 'superposition' of states. It's not in a definite state until we measure it, and beforehand we can only assign probabilities to the likely outcome.

Non-locality: spooky action at distance

Take a pair of entangled particles, change the properties of one and the other will change instantly. Einstein called this 'spooky action at distance' and was deeply disturbed by it.

WHY THEY DON'T AGREE

Gravitational fields aren't in a superposition

According to Einstein, a gravitational field cannot be here and there, yet according to quantum theory the matter and energy that warp space-time to create it can. Something has to give.

You often get the answer 'infinity'

Other calculations give the answer infinity when you try and calculate physical quantities. Infinity is a glaring neon signpost saying you've got the physics wrong. You cannot have an infinite amount of energy, for example.

Gravity doesn't have a boson

There are four fundamental forces: gravity, electromagnetism and the strong and weak nuclear forces. Quantum physics says the last three forces act between objects through the exchange of particles called bosons. No one has found a boson for gravity.

You get probabilities higher than one

Probabilities run from zero for impossible to one for certain. Combining quantum physics and relativity at high energies gives probabilities higher than one. You can't be more certain than certain.

GENERAL RELATIVITY

The speed of light is sacrosanct

Nothing can travel through space faster than the speed of light, yet entangled particles appear to defy this rule. As of yet there is no agreed explanation for this phenomenon.

Space and time are space-time

The three dimensions of space and one of time that we experience are really wrapped up together in a four-dimensional fabric called space-time. This fabric is smooth and continuous.

Gravity is geometry

Newton was wrong – gravity isn't a pull from a massive object. Instead it is the effect we see of bodies following a curved path through space-time as the result of a massive object, like a star, warping it.

Acceleration and gravity

The equivalence principle says you cannot distinguish between a gravitational pull and an acceleration. Accelerate through space and you'll experience the same 'gravity' as on Earth.

WHAT DO WE KNOW ABOUT SPACE-TIME?

1 The Big Bang

According to general relativity, space-time began in a singularity 13.8 billion years ago. It has been expanding ever since.

2 The first light

380,000 years after the Big Bang, space-time had cooled enough for atoms to form, and light that had previously been trapped flooded the universe.

3 The first stars

After 100 to 200 million years, slightly denser regions of space-time collapsed to form the first stars. Incredibly massive, they lived fast and died young.

4 The first galaxies

Around a billion years after the Big Bang, stars clustered into dense regions of space-time which drew in even more material to make the first galaxies.

HISTORY OF SPACE-TIME THEORIES

100 CE

The Ptolemaic model

Claudius Ptolemy creates a model with Earth at the centre of creation with the Sun, Moon and planets orbiting around us. There's no explanation of why they behave that way.

1543

Copernicus publishes his heliocentric model

Polish mathematician Nicolaus Copernicus argues that the Sun is in the centre of the Solar System. His book *De revolutionibus orbium coelestium* is one of the most important scientific texts of all time.

1687

Newton's book *Principia* is published

In his landmark work Newton sets out his law of universal gravitation. All masses attract all other masses in space with a force related to the distance between them.

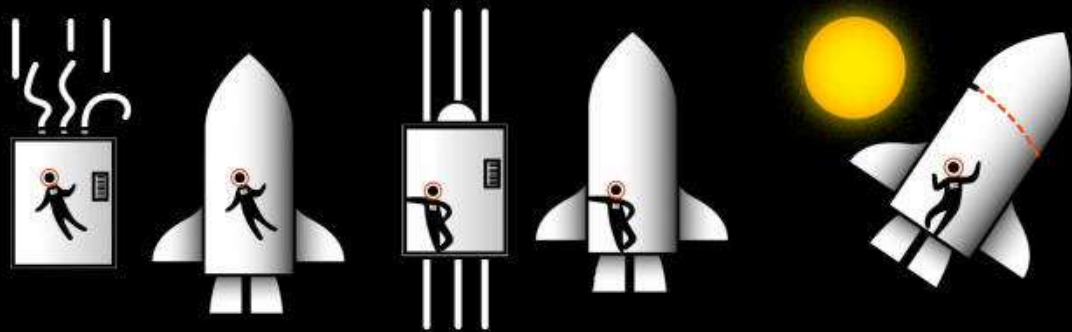
1803

John Dalton proposes indivisible atoms

The English chemist says that all matter is made up of tiny, unbreakable and indestructible building blocks called atoms. He was able to successfully explain a lot of chemistry using this idea.

0 100 200 300 400 500 600 700 800 900 1000

GENERAL RELATIVITY EXPLAINED



Free fall and floating

Einstein realised that free-falling because of gravity is the same as floating with no gravity. He concluded that gravity cannot be a force, as Newton had said.

Gravity and acceleration

Accelerating in a vehicle pushes you into your seat. Gravity and acceleration feel the same, so they have the same cause: a curved path through space-time.

The bending of light

Light from a torch would appear to bend as you accelerate. Acceleration is the same as curved space-time, so light should also be bent by it.

continuous fabric Einstein suggested. According to Einstein, space-time is like a stage that remains in place whether actors are treading its boards or not - even if there were no stars or planets dancing around, space-time would still be there. However, physicists Laurent Freidel, Robert Leigh and Djordje Minic think that this picture is holding us back. They believe space-time doesn't exist independently of the objects in it. Space-time is defined by the way objects interact. That would make space-time an artefact of the quantum world itself, not something to be combined with it. "It may sound kooky," says Minic, "but it is a very precise way of approaching the problem."

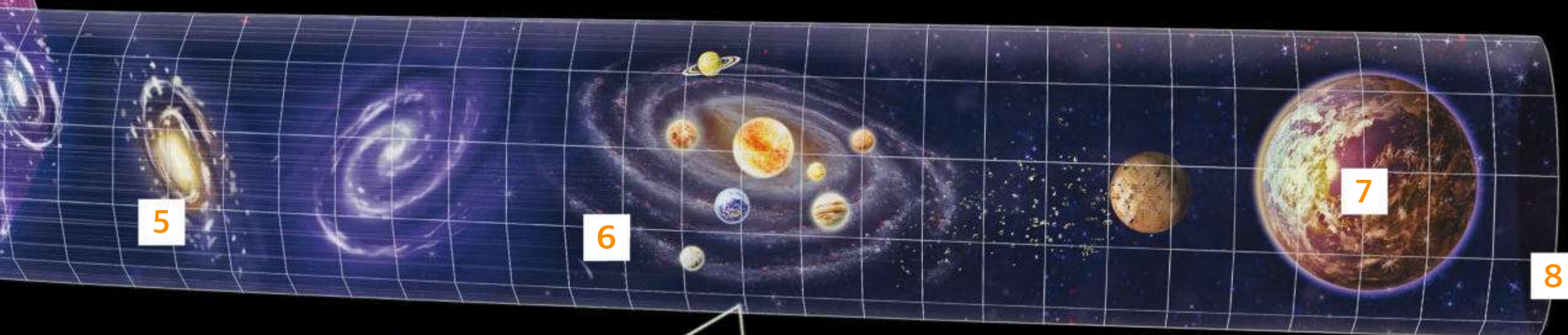
The attraction of this theory - called modular space-time - is that it might help solve another long-standing problem in theoretical physics regarding something called locality and a notorious phenomenon in quantum physics called entanglement. Physicists can set up a situation whereby they bring two particles together and link their quantum properties. They then separate them by a large distance and find they are still linked. Change the properties of one and the other will change instantly, as if information has travelled from one to the other

5 The universe accelerates

Having gradually slowed since the Big Bang, space-time begins to stretch at an accelerating pace due to something called dark energy.

7 The here and now

Today Earth is home to physicists who are pondering how best to combine quantum theory with Einstein's picture of space-time.



6 The Sun forms

Around 4.6 billion years ago a cloud of gas collapsed to form the Sun. Space-time is warped so much that planets soon form around it.

8 The Big Rip

As dark energy takes hold, the universe will eventually expand so much that even the space between atoms is stretched sufficiently to tear the universe apart.

1915

Einstein publishes the general theory of relativity

In a direct challenge to Newton's idea, Einstein says the force of gravity is a mirage. Instead it is caused by the curvature of the four-dimensional fabric of space-time.

1919

Eddington eclipse vindicates Einstein

Observations of a 1919 solar eclipse by English astronomer Arthur Eddington showed that the Sun bends light by the exact amount predicted by Einstein's general theory of relativity.

1974

String theory arrives on the scene

Dalton's idea of indestructible atoms looks even more outdated as the electrons found inside atoms are proposed to themselves be made of tinier vibrating strings vibrating across multiple dimensions.

1988

Loop quantum gravity emerges

Physicists including Lee Smolin and Carlo Rovelli formulate the basic principles of LQG - a way of thinking space-time might be made of building blocks in the same way matter is constructed from atoms.

1100

1200

1300

1400

1500

1600

1700

1800

1900

2000

2100



REPLACING SPACE-TIME

String theory

Fundamental particles such as electrons are made of tiny strings that vibrate across ten spatial dimensions, plus one time dimension. This picture manages to avoid infinities when combining quantum theory and general relativity, but it cannot currently be tested.

Loop quantum gravity (LQG)

Space-time is not a smooth fabric, but is made up of a network of tiny stitches instead. This is potentially testable by looking at light reaching us from gamma-ray bursts (GRBs) in the distant universe.

Modular space-time

Space-time is only a stage when it has actors on it. In other words, interactions between objects create space-time. This can potentially explain the quirks of non-locality and quantum entanglement.

Supergravity

This is the combination of general relativity with a popular but unproven theory called supersymmetry – the same theory is the leading candidate to explain dark matter.

Causal set theory

Space-time is not a continuous fabric, but does have a structure based on regions that have a link between past and future. It is based on work by David Malament and Rafael Sorkin.

faster than the speed of light. Einstein was so perturbed by this phenomenon that he called it 'spooky action at a distance'.

Modular space-time can accommodate such behaviour by redefining what it means to be separated. If space-time emerges from the quantum world, then being closer in a quantum sense is more fundamental than being close in a physical sense. "Different observers would have different notions of locality," says Minic, "it depends on the context." It's a bit like our relationships with other people. We can feel closer to a loved one far away than the stranger who lives down the street. "You can have these non-local connections as long as they are fairly small," says Hossenfelder.

Freidel, Leigh and Minic have been working on their idea for the last eight years, and they believe they are slowly making progress. "We want to be conservative and take things step by step," says Minic, "but it is tantalising and exciting." It's certainly a novel approach, and one that looks to 'gravitationalise' the quantum world rather than quantising gravity as in LQG. Yet as with any scientific theory, it needs to be tested. At the moment the trio are working on how to fit time into their model.

"WHETHER IT DESCRIBES THE SPACE-TIME IN WHICH WE LIVE, WE DON'T REALLY KNOW UNTIL THERE IS AN EXPERIMENT" JORMA LOUKO

This may all sound incredibly esoteric, but it could have a more profound effect on our everyday lives. "We sit in space, we travel through time, and if something changes in our understanding of space-time this will impact not only on our understanding of gravity, but of quantum theory in general," says Hossenfelder. "All our present devices only work because of quantum theory. If we understand the quantum structure of space-time better, that will have an impact on future technologies – maybe not in 50 or 100 years, but maybe in 200," she says.

The current monarch is getting long in the tooth, and a new pretender is long overdue, but which of the many options is most likely to succeed? When we decide, the resulting revolution could bear fruit not just for theoretical physics, but for all.

Above: One way to reconcile general relativity and quantum theory says reality is made of vibrating strings



STAY POWERFUL

CELESTRON POWERTANK LITHIUM POWER PACKS

Whether you need to recharge your phone or power a weekend stargazing marathon, Celestron's PowerTank Lithium line has you covered. Each of our power solutions was developed specifically with astronomers in mind, with unique features and a focus on safety.

10 YEAR
SHELF LIFE



POWERTANK LITHIUM PRO

- Our largest power pack with **up to 17 hours** of telescope power
- Car battery port, 2 USB ports (including a quick-charge port) and a red/white flashlight
- Lithium iron phosphate (LiFePO_4) battery chemistry



NEW POWERTANK GLOW 5000

- A must-have accessory for amateur astronomers: a red LED flashlight plus a USB power bank for charging mobile devices in the field
 - Rechargeable 5,000 mAh lithium-ion battery delivers a full recharge to smartphones
 - Lithium cobalt oxide (LiCoO_2) battery chemistry



NEW POWERTANK LITHIUM LT

- Our smallest and lightest telescope power pack
 - Unlike competitors, delivers regulated 12V power for **up to 8 hours** for optimum telescope performance
 - Quick-charge USB port
- Lithium nickel manganese cobalt oxide (LiNiMnCoO_2) battery chemistry



10-YEAR
SHELF LIFE

POWERTANK LITHIUM

- **Up to 10 hours** of power
- 2 USB ports and a red/white flashlight
- Lithium iron phosphate (LiFePO_4) battery chemistry

POWER UP AND GO

Our team at Celestron designed the PowerTank Lithium LT, PowerTank Lithium and PowerTank Lithium Pro specifically for astronomy. The high-quality battery keeps a consistent voltage until the last 30 minutes of its life, and the form factor is perfect for telescopes, including straps to attach it to tripod legs. By placing the battery on the tripod leg you can keep your cords short and out of the way, eliminating trip hazards and cord wrap issues.

Find out more at celestron.com or contact Celestron UK on 0118 4671 200

celestron.com

Instant expert

WHAT IS ZODIACAL LIGHT?

If you go to an area with low light pollution, you may notice that the western sky in the evening appears bright even after twilight. The dim light appears to be distributed from the ecliptic plane and lingers until late evening. A similar phenomenon occurs in the morning towards the east. This is zodiacal light. It is a phenomenon where dust particles near Earth are illuminated by sunshine and the light is reflected towards ground-based observers.

Astronomers have debated for over a century about the origin of the dust particles. As is well known, comets - small icy bodies from the outer Solar System - eject dust and gas when they approach the Sun. Asteroids also emit dust due to collisions or rapid rotation. Some asteroids in the outer asteroid belt - between the orbits of Mars and Jupiter - may contain ice underneath and eject dust together with gas. These small bodies of the Solar System are significant dust sources that become observable as zodiacal light.

The contribution of dust particles from beyond the Solar System used to be discussed, but was conjectured to be ignorable. However, motivated by the recent discoveries of interstellar comets such as 'Oumuamua, astronomers may consider the contribution of interstellar dust once again.

Before modernisation, it should have been possible to observe zodiacal light from almost every part of the world, with records of it being visible from the centre of Tokyo, Japan, during World War II. However, due to rapid industrial growth and the increase of artificial light around us, zodiacal light has been obscured behind severe haze and light pollution. The night sky illuminated by artificial light is indistinguishable from zodiacal light and, for this reason, it is now challenging to observe this phenomena in most areas of the world.

1 Where should you be looking?

Three words: follow the ecliptic. The ecliptic is the imaginary path in the sky that the Sun follows. This will reveal where the star sets and rises and whether you should look east or west.

2 When is the best time to see it?

The times will vary depending on the seasons and your position on Earth, but it can be seen an hour before sunrise and an hour after the sunset. This is dependant on minimal light pollution.



BIO PROFESSOR MASATERU ISHIGURO

Japanese scientist Ishiguro is a professor in the department of physics and astronomy at Seoul National University, South Korea. His main area of research revolves around primitive bodies in the Solar System, especially interplanetary dust particles. His research means he is something of an expert when it comes to zodiacal light, having investigated it for a quarter of a century.

4 Is it similar to the Milky Way?

Although it does give off a rare celestial glow, zodiacal light and the Milky Way are not comparable. The Milky Way glows due to the shining of millions of stars, whereas zodiacal light is reflecting the Sun's light via debris.

3 How would you recognise it?

It can be best described as a pyramid of light coming from the horizon - it can stretch out around 20 or 30 degrees along the horizon - and has an eerie and hazy glow to it.

3

2

1

INTERVIEW BIO

Dr Nour Raouafi

Raouafi is a Tunisian astrophysicist at Johns Hopkins University's Applied Physics Laboratory (APL) in Maryland and the project scientist for NASA's Parker Solar Probe mission. He is an expert in many solar and heliospheric topics, including solar magnetic fields, coronal plumes and jets, coronal mass ejections (CMEs), solar wind, solar energetic particles and many other areas.

For the last two years the Parker Solar Probe has been beaming back unique data sets while breaking records when it comes to how close a human-made object has been to the Sun and how fast it travels. Its latest encounter reached within 18.7 million kilometres (11.6 million miles) of the Sun and sped past at 393,000 kilometres (244,225 miles) per hour.

PARKER SOLAR PROBE: TWO YEARS ON

"THIS COMING DECADE WILL BE THE GOLDEN AGE OF SOLAR AND HELIOPHYSICS RESEARCH"

All About Space catches up with the project scientist for NASA's incredible Parker Solar Probe mission, Dr Nour Raouafi – a spacecraft continuously breaking records and surpassing all expectations as it orbits the Sun

Interviewed by Lee Cavendish

How's the Parker Solar Probe doing? Are there any updates that we should be aware of?

The Parker Solar Probe is doing great. We are going through our fifth encounter and recently we were the closest we've ever been to the Sun. After a period of five days where we could not communicate with the spacecraft, it sent us a signal that it's healthy and it's doing what it's supposed to do. In terms of science, it's just amazing. Whenever the spacecraft gets closer to the Sun, we are learning new things that we've never seen before.

What is the major mystery surrounding the Sun and its corona that astronomers are desperately trying to solve, and are hoping the Parker Solar Probe will help shed light on?

There are a few phenomena that were discovered decades ago, but we are still struggling to understand. I think the one that is most puzzling is what we call the 'coronal heating problem'. The corona, which is the outermost layer of the solar atmosphere, is 300-times hotter than the solar surface. And we know that all the energy is coming from inside the Sun, so in a way it's counter-intuitive that the source is cooler than the environment around it. But the Parker Solar Probe is giving us clues and hints as to what might be causing excess heating there.

Another phenomenon, which is very closely related to coronal heating as well, is what we call the acceleration of solar wind. The solar wind is a flow of charged particles – electrons, protons,

ionised helium and heavy elements – that are constantly flowing away from the Sun to the rest of the Solar System. The issue with the solar wind is that low down [within the solar atmosphere] these particles are flowing at very slow speeds, but they get accelerated to hundreds of kilometres per second in a very short distance. We don't know exactly what is the physical mechanism that gives them the energy to accelerate to these high speeds.

The third phenomenon, and we are impacted by it every day, is big explosions on the Sun. Whenever there is a flare or a coronal mass ejection (CME) erupting on the Sun, there is a population of particles that get accelerated to almost the speed of light. We call them solar energetic particles.

The Parker Solar Probe was built specifically to be able to shield its instruments in a really dangerous environment. How has its heat shield been constructed so that it can withstand such dangerous temperatures and radiation while remaining relatively lightweight?

The heat shield is basically made of carbon foam. Most of it is a vacuum. It's like a sponge made out of carbon that is sandwiched between two sheets, which are also compressed carbon. The other thing that is specific to the Parker Solar Probe is a plasma spray that is white and is on top of the heat shield. The goal here is to reflect as much light from the Sun as possible.

When we are closest to the Sun in 2024, that side of the heat shield will be more than 2,500 degrees

Fahrenheit [1,371 degrees Celsius]. 4.5 inches (11.5 centimetres) inward, which is the other side of the heat shield, will be at almost 700 degrees Fahrenheit [371 degrees Celsius], so there we have already lost a lot of heat. And from that backside of the heat shield to the bus, where the instruments are mounted, it is at room temperature.



Right: The closest-ever approach to the Sun planned for the Parker Solar Probe will occur in 2024.

© NASA

Interview Dr Nour Raouafi

What impacts can space weather and solar wind have to us on Earth?

Let me start by saying, we are now starting to think about sending women and men to the Moon, and maybe to Mars in the near future. If we are going to do that, we need to protect these people out there. We cannot just launch them out there. If we don't protect them sufficiently, these solar energetic particles will not be good for them and also for the space equipment. It will have a different impact on our environment here on Earth and also the other planets as well.

Just as a simple example: we rely a lot on GPS, which is functional because we have spacecraft orbiting Earth. And if there is a big explosion on the Sun and it burns some of these satellites out, some of us will be in trouble because GPS will not be working anymore.

Another example is if we have a huge CME or flare that will cause a humongous geomagnetic storm here on Earth - that can cause a shutdown of power grids. That will be devastating for the economy and for the societal fabric. That's actually why space weather is a big topic now for research and for all of us here.

It's been two years now since the Parker Solar Probe was launched. Do you have any favourite moments or a favourite result that has come from the mission so far?

A lot of them. One of my favourite moments - I may not have enjoyed it when it happened, but now with hindsight I enjoyed it a lot - was the launch of the mission. I mean, we have been waiting for the Parker Solar Probe for 60 years, and on 12 August 2018 we put it on top of the most powerful rocket in existence, and all you hope for is that everything goes smoothly. I was so stressed when I was watching it, and it all went really well.

But after that, what we have discovered is something amazing. The spacecraft we designed at APL is functioning way better than we had thought it would. What we are getting back from this machine is amazing. Let me give you an example in terms of science data: we are bringing three to four times the volumes we thought we would do pre-launch. We also thought pre-launch that we were only going to operate instruments when we were close to the Sun and after launch. We are now basically operating the instruments almost all of the time.

The planned mission duration is currently seven years. Do you think it could possibly reach ten years or more?

If by the end of the seven years, if everything is going well, it's a no-brainer that we will request an extension of the mission. During these seven years we will have basically covered half of the solar cycle. We launched at the minimum, and by

2025 we will be at the maximum of the solar cycle. What I want to see from the Parker Solar Probe is to basically complete a whole cycle, going from the maximum to the other minimum, which is an extension of the mission by five to six years. I would love to see that.

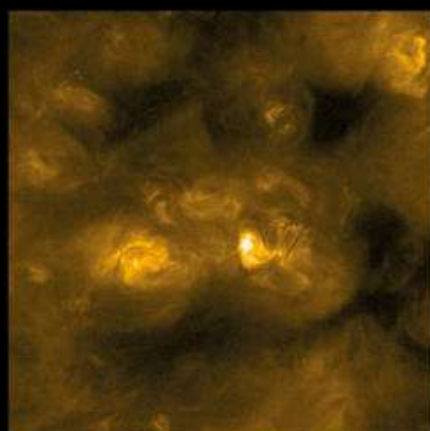
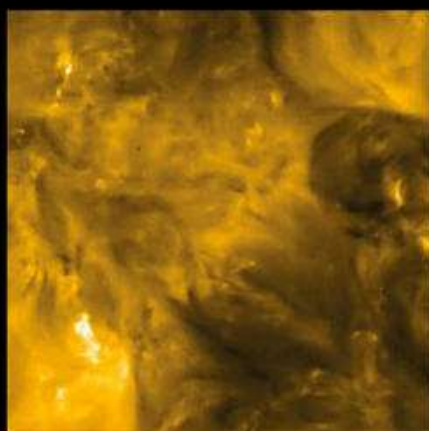
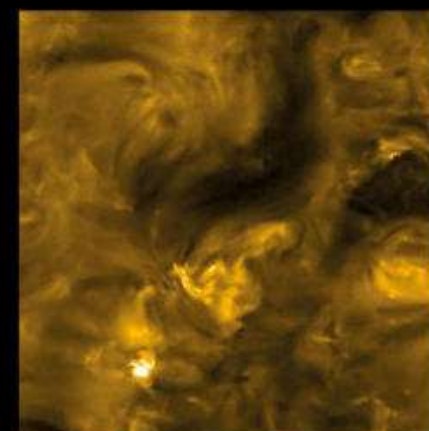
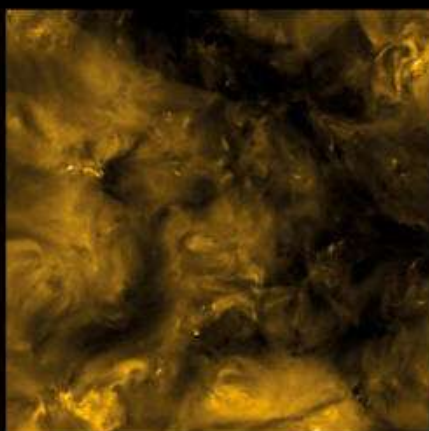
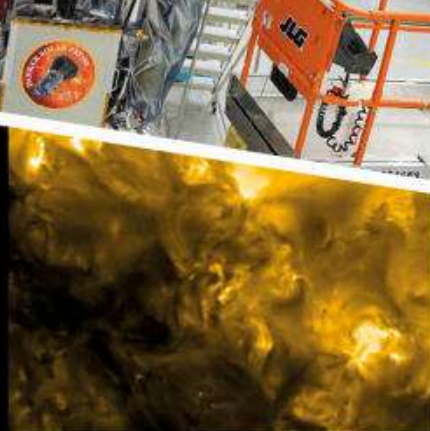
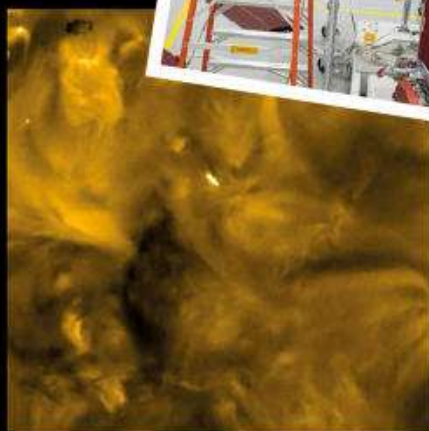
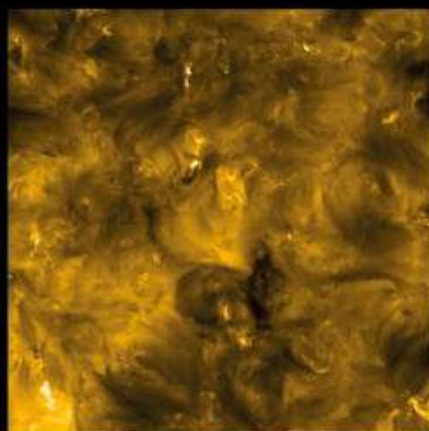
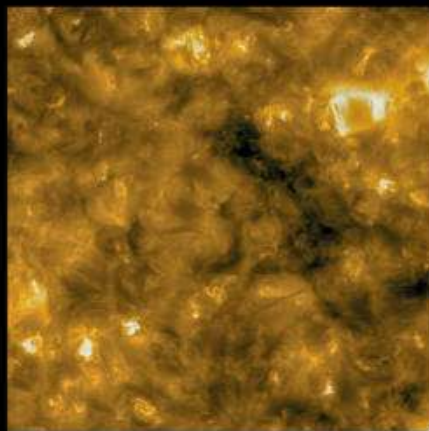
Could this information be used for stars beyond our Solar System as well?

That's a very good remark. By understanding how the Sun works, we can actually project all we gain from what we learned about the Sun to other stellar systems. Other stellar systems are so far away that we cannot study them in detail as we are currently doing with the Sun. What we learn from the Parker Solar Probe, by explaining all these big phenomena we talked about at the beginning, we can basically take that and project it onto other stellar systems - and why would you want to do that?

It's because we are so curious about whether there are other planets out there and whether there is habitability around other stars. The interaction between the stars and the planets is so crucial for life and for habitability. By understanding how the Sun behaves and how it interacts with us here on Earth and other planets, it will help us tremendously in understanding other stellar systems. In a way the Parker Solar Probe is our ambassador to other stellar systems as well, as it will help us understand other stellar systems.

Top: The heat shield is an integral part of the spacecraft and keeps the instruments at room temperature

Right: Solar Orbiter's Extreme Ultraviolet Imager (EUI) has recently revealed omnipresent tiny solar flares, now referred to as 'campfires'



In December 2019 news came out around the Parker Solar Probe regarding the release of the first year of scientific results. Could you explain some of the main news stories that came out after this first year?

That was really an ideal time for the Parker team, but also for everybody. For humanity. Flying a spacecraft around this star is something very challenging. In terms of science, it was amazing. But before going into this, let me say this. You will have to wait a little bit, probably a few months, and you will be seeing another wave of big discoveries from the Parker Solar Probe. We just got the new data from orbit four, which is the closest perihelion to the Sun, and we are seeing new things that we have not seen before.

Going back to what we released in December and later on in February in a special issue in the *Astrophysical Journal*, there are a key number of discoveries that are breakthrough discoveries. One of them is what we call the 'dust-free zone'.

When you look at the heliosphere, there is dust almost everywhere. The dust comes from asteroids and comets that grind up in the Solar System, but the closer the dust particles get to the Sun, the smaller they get. At a certain point they will evaporate. The result of that is you create a zone around the Sun where there is no dust. This was hypothesised in 1929, and since then people have looked for it over and over again, but nobody has seen it. The Parker Solar Probe is giving the first hints that this dust-free zone exists.

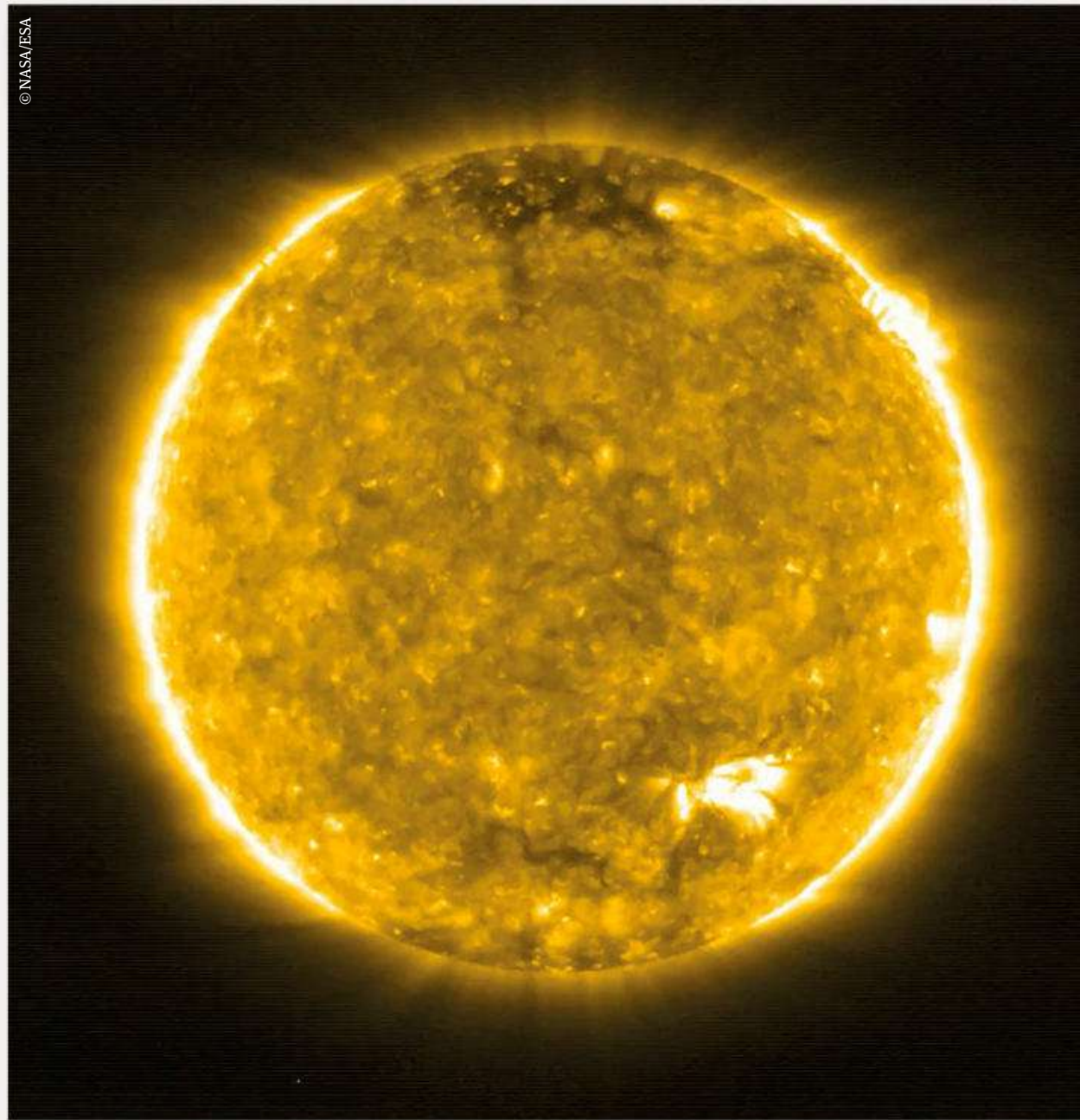
The objectives of the mission are obviously to explain the heating and the acceleration of the plasma in the coronal heating and acceleration of the solar wind. In other terms, what we are looking for are energy sources that we cannot see from Earth, and the Parker Solar Probe is giving us one possible smoking gun.

When the Parker Solar Probe got closer to the Sun, it saw kinks in the magnetic field. Magnetic fields essentially make an S-shape. They bend all the way back to the Sun and outward again in a matter of a few tens of seconds to several minutes. The reason why this is so important is that you cannot do that to a magnetic field easily. Creating this structure and maintaining it means that there is a big source of energy creating that. That's exactly what we are looking for.

Surely with this mission, the fact that it's achieving so many milestones and performing so well, that's going to inform what kind of mission you could do next, and what sort of boundaries you could push.

You are touching on a very sensitive nerve there. Go back in history to the 1960s. There was a committee that proposed three key missions that NASA had to implement. One of the missions was a probe that orbits the poles of the Sun, which has already been implemented. This was the Ulysses mission. Now

Right: Our Sun from the first batch of solar images taken by ESA/NASA's Solar Orbiter on 30 May 2020



that mission is over. The second one is a probe that will orbit the Sun within the orbit of Mercury. That is the Parker Solar Probe. We did it after 60 years. It has been challenging, but we did it.

The third one is a probe that will fly out of the Solar System, very, very far away. We are working on that, but why have we started working on that? It's because we realised the success of the Parker Solar Probe.

Now the community is so bold. Realising that a challenging mission like the Parker Solar Probe can be so successful, we are able to do it for other missions as well. The outer solar probe is certainly one of them. It's an extremely challenging mission, but we started working on it at APL and hopefully one day it will see the light.

There is another idea out there, which is having a solar polar mission, which is an amazing mission. This is a mission that will fly above the poles of the Sun for an extended period of time, and that's also not easy at all. Getting a spacecraft out of the ecliptic is extremely hard, but again, realising the success of the Parker Solar Probe is pushing the community to be bold and start thinking about these big challenges.

The European Space Agency (ESA) recently launched the Solar Orbiter spacecraft in collaboration with NASA. Are there any plans to coordinate on observations with the Parker Solar Probe and the Solar Orbiter?

These two solar missions can complement each other in many ways. I can tell you that working together will provide the scientists - and also everybody else - with way more than the sum of the two missions.

I'm almost sure that with these two missions, and also if you add DKIST, the Daniel K. Inouye Solar Telescope, which is a large solar telescope in Hawaii, this coming decade will be the golden age of solar and heliophysics research.

I don't think we have ever witnessed the amount of enthusiasm around the Parker Solar Probe, Solar Orbiter and DKIST as we are seeing now, and honestly we have never been able to achieve this much in such a short amount of time. Having a mission that is approaching the Sun like never before, having another mission that is flying above the ecliptic to see the poles for the first time and also having the largest solar telescope on the ground... it's amazing.

HOW BIG IS ANTARES?

Using the best radio telescopes in the world, this local red supergiant star has recently been mapped in extraordinary detail

Reported by Lee Cavendish

0.7^{TO} 100
MILLIMETRES

The wavelength range that Antares was observed in using the two radio telescopes.

Below: ALMA currently holds the title of the world's largest radio telescope

The night sky, especially when viewed from an area with low to no light pollution, can reveal a beautiful array of celestial gems – twinkling stars that generations before have marvelled at. The difference between then and now is that our generation has the capability to map these stars with precision. New research has taken this to a whole new level by mapping the famous star Antares, learning more about its atmosphere and how this can be applied to other red supergiant stars.

Throughout the years people have gazed upon ruddy Antares, the brightest star in the constellation of Scorpius and one of the brightest stars in the night sky, which lies 554 light years from Earth. As telescopes, spectroscopy and multi-wavelength observations have become more advanced, we have been able to learn more about the stars. Scientists have been able to categorise Antares as a red supergiant star that has swollen as it approaches the end of its life, despite it being only 11 million years old. By comparison the Sun is 4.6 billion years old. This is because Antares weighs 12 solar masses – 12 times the mass of our Sun – and with stars the biggest and brightest burn out the quickest. Astronomers have deduced over many years of visible-light observations that Antares is approximately 700-times wider than the Sun, and previous research into its climate has suggested that the temperature of the red supergiant star's chromosphere should be between 5,700 and 12,700 degrees Celsius (10,000 and 22,900 degrees Fahrenheit).

Now the plot has thickened as researchers have been able to map the atmosphere of Antares with unprecedented levels of precision, revealing unusually cool regions residing in localised bubbles in addition to highlighting the true extent of the star's impressive stellar wind. This research was only made possible by utilising two of the



Famous red supergiants

Antares

Constellation: Scorpius
Distance: 554 light years
Age: 11 million years
Solar masses: 12
Solar radii: 700

VY Canis Majoris

Constellation: Canis Major
Distance: 3,820 light years
Age: 8.2 million years
Solar masses: 17
Solar radii: 1,420

Betelgeuse

Constellation: Orion
Distance: 700 light years
Age: 10 million years
Solar masses: 11
Solar radii: 890

Mu Cephei

Constellation: Cepheus
Distance: 5,258 light years
Age: 10 million years
Solar masses: 19
Solar radii: 1,650

CE Tauri

Constellation: Taurus
Distance: 1,794 light years
Age: 14 million years
Solar masses: 14
Solar radii: 587

most powerful tools in radio astronomy: the Atacama Large Millimeter/submillimeter Array (ALMA) located in the Atacama Desert, Chile, and the National Science Foundation's Karl G. Jansky Very Large Array (VLA), located in New Mexico. Dr Eamon O'Gorman of the Dublin Institute for Advanced Studies in Ireland and his team have been able to measure the temperature and size of Antares' stellar atmosphere, publishing their results in a new scientific paper.

"We had looked at Betelgeuse a lot already at radio wavelengths, albeit with the old VLA, and at one wavelength with ALMA," O'Gorman tells **All About Space**. "Antares is the only other red supergiant that can currently be resolved at radio wavelengths, so we decided to focus on it. We could then compare our results to what we already knew about Betelgeuse."

However, something unexpected arrived in the results. "[The results] have revealed a new 'lukewarm' chromosphere component," explains paper co-author Dr Keiichi Ohnaka, associate professor at the Universidad Católica del Norte in Chile, to **All About Space**. "It is not known why the temperature goes up in the chromosphere instead of falling off, so this new lukewarm component is important for deciphering the heating mechanism of the chromosphere."

"[This discovery] is important firstly because we have managed to resolve a star's atmosphere at many different radio wavelengths, a feat which is very, very difficult to do," says O'Gorman. "These observations allowed us to find out a lot about the size and temperature of the chromospheres of red supergiant stars."

But what exactly is the chromosphere? "A chromosphere is an atmospheric layer just above a star's surface that is heated to high temperatures

This is the first time another star's chromosphere has been detected and measured using radio waves.

by mechanisms due to the motion of the plasma taking place beneath or on the star's surface. This had never been detected at radio wavelengths before for an evolved star," explains O'Gorman. "The inhomogeneous nature of

the chromosphere is the result of the complex environment that exists in the atmospheres of these stars - Antares and Betelgeuse - and stars in general," he continues.

Astronomers had already deduced that Antares is roughly 700-times wider than the Sun; it would extend to somewhere around the asteroid belt if it was placed into the Sun's spot at the centre of our Solar System. Now the star's chromosphere through to the region containing its stellar wind have been mapped in unrivalled detail using ALMA for shorter wavelengths and the VLA for longer wavelengths. These new results have shown that the chromosphere is 'lukewarm' at best. The temperatures peak around 3,500 degrees Celsius (6,400 degrees Fahrenheit) and then gradually decrease the further out it gets from the energy source. This is minuscule compared to the Sun's chromospheric temperature of around 20,000 degrees Celsius (36,000 degrees Fahrenheit).

"[This result] does not mean that the temperatures of 5,700 to 12,700 degrees Celsius (10,000 to 22,900 degrees Fahrenheit) from the previous works are wrong. Such hot gas does exist. If we take into account the infrared images of Antares, there should also be cool gas at temperatures lower than 1,700 degrees Celsius (1,400 degrees Fahrenheit)," says Ohnaka. "Therefore we conjecture that both 'hot' and 'lukewarm' chromospheres, as well as cool gas, may coexist in distinct cells or pockets. As we think that Antares and Betelgeuse are representative of red supergiants, the inhomogeneous atmosphere is probably a usual trait in this class of star."

The inhomogeneous nature of Antares is an extremely intriguing aspect in itself. It appears that because of the evolved nature of the star the temperature decreases in random pockets of the star's atmosphere, and the mysterious magnetic fields and shock waves emanating from the star's surface are the reason for this.

Something else that the study revealed is the true size of Antares, as the chromosphere stretches out to 2.5 times the star's radius - extraordinary considering the Sun's chromosphere is only 0.5 per cent of its radius. However, astronomers' current understanding of heliophysics is limited, and they are still unable to understand these different features, factors and mechanisms for our own Sun, let alone a star over 550 light years away.

When O'Gorman and his team observed Antares in longer wavelengths, courtesy of the VLA, they were able to make a clear distinction between the chromosphere and the region where Antares' stellar wind begins to form. This is the first time

Left: The VLA is comprised of 28 25-metre (82-foot) radio telescopes

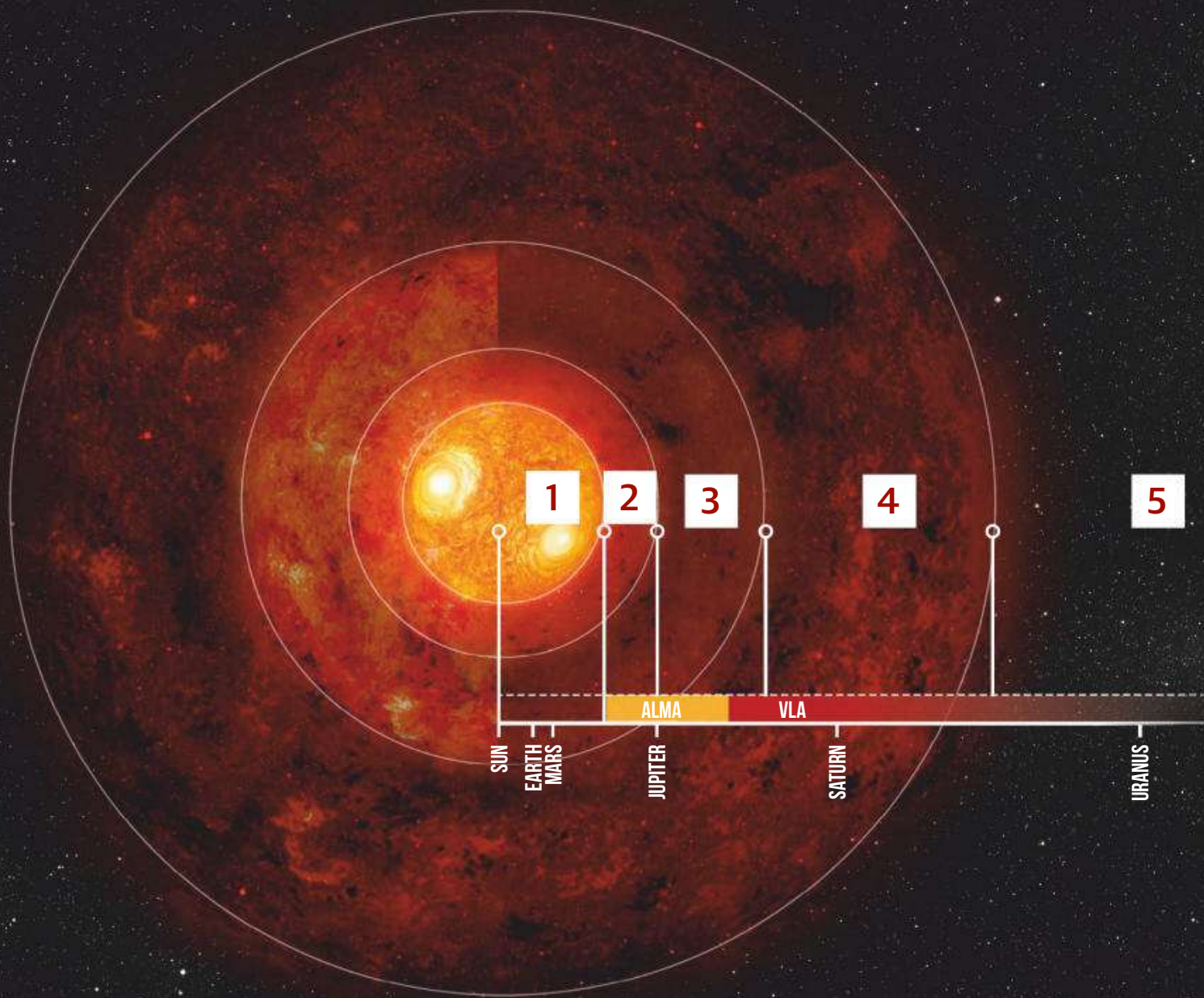
Right: Red supergiant stars eventually phase into an extravagant supernova explosion



© NRAO

The latest look at Antares

ALMA and the VLA combined their powers to break down the atmospheric layers of a star over 550 light years away



1 Photosphere

This is commonly referred to as the star's 'surface'. Sunspots and faculae usually occur on the photosphere. In Antares' case its face is burning at roughly 3,400 degrees Celsius (6,200 degrees Fahrenheit).

2 Lower chromosphere

This layer was observed in the shortest wavelength ALMA has to offer. The temperature of the gas in this region is approximately 2,400 degrees Celsius (4,400 degrees Fahrenheit).

3 Upper chromosphere

The space between the upper and lower chromosphere would be the equivalent of Jupiter's orbit around the Sun. The temperature peaks in this region at about 3,500 degrees Celsius (6,400 degrees Fahrenheit).

4 The wind acceleration zone

The VLA was able to study this region in longer wavelengths, and the results show that this region is roughly 2,600 degrees Celsius (4,700 degrees Fahrenheit). It is unknown what accelerates the stellar wind.

5 Wind

Stellar wind, illuminated in this research by Antares B, appears relatively cool at less than 1,500 degrees Celsius (2,700 degrees Fahrenheit). This wind carries heavy elements into the universe.

10,000

At visual wavelengths, Antares is 10,000-times brighter than the Sun.

this distinction has been detected, and it is shown in amazing clarity. The images that the VLA took show a huge gust of stellar wind that is illuminated by Antares B, Antares' smaller but hotter companion star. This wind is carrying stellar material out into the cosmos. At the start of Antares' life it had a mass 15 times that of the Sun, but has lost three solar masses worth of material during its lifetime. This all originates from the interior of the star.

In the interior of a red supergiant there is more than just hydrogen and helium and the occasional bit of lithium burning, as in most stars. Instead there is an iron core with layers of different elements being burned to keep the star shining for just a little bit longer. These layers contain carbon,

oxygen, nitrogen and so on, which can all find themselves in the stellar wind and sent out into star-forming clouds throughout the cosmos. This is similar to the elements that were once in the Solar System's original cloud of dust and gas. This is the carbon that is the basis for our DNA, the oxygen we breathe and the nitrogen that makes up most of Earth's atmosphere.

There are so many stars in the night sky, each with its own story, and only by investigating them in all sorts of wavelengths and using different methods can we begin to build a firm understanding of how all stars differ, how they evolve and their overall influence on the cosmos.



WHAT HAPPENS WHEN WE CONTACT ALIEN LIFE?

Preparing the world for the biggest
discovery in the history of humanity

Reported by Jonathan O'Callaghan

In August 2016 the entire world was gripped with the news that a possible signal from an intelligent alien race had been received. Picked up by a Russian radio telescope, its discoverers had no explanation for the signal, which appeared to be artificial, and suggested it could be our first sign of alien life. Alas, it was not to be. The signal, like so many before it, turned out to be interference from Earth, most likely a satellite in orbit. But the event highlighted a key point – there is a huge public clamour for finding extraterrestrial (ET) life, and when it happens it is likely to be the biggest story in human history.

Most of our searches for intelligent alien life have been primitive and poorly funded. At the moment, perhaps the most well-known organisation leading the charge is the SETI (Search for Extraterrestrial Intelligence) Institute in California, which performs searches with a suite of antennae known as the Allen Telescope Array. But there are other groups and organisations around the world involved in the hunt too. For the most part it's a small community. Information is shared, discussions are held and the ramifications of a discovery are considered.

More recently Russian billionaire Yuri Milner invested \$100 million (about £79 million) in the Breakthrough Listen project, a ten-year initiative to buy telescope time and accelerate the search for life. The uncomfortable truth at the moment, however, is that we haven't heard anything, despite decades of searching. With 100-400 billion stars in our galaxy – most thought to host at least one planet – and 2 trillion galaxies in the universe, there are a lot of potential homes for life out there... so where is everyone? "There have been a couple of times

“DESPITE EVIDENCE SUGGESTING THERE SHOULD BE PLENTY OF HABITABLE WORLDS OUT THERE, WE STILL HAVEN'T HEARD ANYTHING”

where we've got excited about something," Gerry Harp, the director of the Center for SETI Research at the SETI Institute, tells **All About Space**. "But we've never seen anything that could remotely be a signal from ET." The obvious reason why is that we just haven't looked hard enough yet. In its early days SETI relied on a catalogue of several thousand potentially habitable systems, called HabCat, to direct the searches. But since the launch of NASA's Kepler space telescope in 2009, thousands of planets have now been found – some of them similar to Earth – and are attracting our attention. Once planets were thought to be rare, but now we know they are common, even plentiful.

The stars we're looking at have changed too. Originally searches focused on stars like our own Sun. After all, we know Earth has life – why not look for a world similar to our own? But we now know that red dwarfs, much smaller stars, make up 80 per cent of the stars in the sky, and they might be habitable to life too, so have been added to the search. Space is also unforgiving, even to radio or electromagnetic transmissions. It's likely that if there is intelligent life out there, we'll need bigger and more powerful telescopes to listen to them.

Below:
The Allen Telescope Array is an important tool in our hunt for alien life



Source: Wikipedia Commons © Kathleen Franklin

Alien contact: who will be the first to know?

The news will hit a number of individuals before the general public is informed

1 The discoverer

An extraterrestrial signal is detected! The discoverer will need to verify the signal several times before revealing to others that it might be a sign of intelligent alien life.



2 Seth Shostak, SETI Institute

As director of the SETI Institute, Shostak is likely to be one of the heads of the institutions that are asked to independently verify the signal.



3 The president

Once confirmed, national authorities will have to be informed of the signal. In the US that would likely include the president, and in the UK, the prime minister.



4 António Guterres, secretary-general of the UN

Broader organisations – including the United Nations – can now start to be told about the groundbreaking new discovery.



5 You

Last, but by no means least, it will be time to publicly and officially inform the world of this amazing discovery – if it hasn't been leaked by the media already.



Source: Wikipedia Commons © Legacy Customs

Source: Wikipedia Commons © Cancillería Argentina

Alien contact

Upcoming projects like the Square Kilometre Array will further our knowledge and bring us closer to a discovery that many think is on the horizon.

To look for signals, astronomers point telescopes to distant stars and listen for irregular patterns on a particular frequency, focusing on radio waves. If an anomaly is found the signal is observed again, and if it disappears it was likely just interference from something on Earth, like a satellite.

If the signal is heard five times from the same point of sky, then things get interesting. At this point the signal would appear to be of alien origin. The SETI Institute uses an automated system to sift through thousands of signals per hour, just ten per cent of which pass the first cut. None of these, of course, have ever passed the final cut, but there have been an estimated 300 million interesting signals found over the years.

SETI's strict protocols usually mean a signal is ruled out as being sent by aliens before the information is leaked to the public. But one day a signal may very well pass these tests. Despite the far-reaching ramifications of this discovery, it will almost certainly be treated like any other scientific finding. Gradually various institutions and organisations will be alerted, and then the fun can begin. "It would be a race to see who would be the first to make sense of the signal," says Harp. "There's a Nobel Prize in unlocking that language."

The first step will be to determine if the signal is just generic noise, like the radio transmissions we send out daily, or a directed message containing a signal. If it's the former then the message will serve simply to tell us that we are not alone, and perhaps we could pick up more errant signals from this distant civilisation. If it's the latter, however, there

may very well be some sort of key, or crib, hidden within that can help us decipher it. "If it has a crib, a directed message, maybe a hello from someone else, then we have a very good chance of deciphering it," says John Elliott from Leeds Beckett University, who is a member of the UK SETI Research Network and has spent much of his research career working out how we'd decipher an alien signal. "It's a bit like meeting someone in the Amazon rainforest who is from a tribe that has never had contact from the outside world. You've only got to point at a tree and say 'tree', or point at a rock and say 'rock', for them to understand that word means that object. That's what the crib would have to do."

Assuming we could decipher it, then things get truly interesting. A heated debate is almost certain to spring up on whether we should respond or not. Many have argued either side of the coin, with some worrying that revealing our presence could invite hostile aliens to come here, pillage our land and destroy humanity. Others are more optimistic, noting that the distances involved would likely be too great to travel over. And if we've spent so much time discovering we're not alone, why would we not respond? "I'm firmly in the camp of yes, we should reply," says Elliott. "I honestly think not to do that would be a waste. The whole point is we want to

“THE QUESTION OF WHETHER WE ARE ALONE IS ARGUABLY ONE OF THE GREATEST UNSOLVED MYSTERIES, AND THE IMPACT OF AN ANSWER WOULD BE FAR-REACHING”



Above:
China's Five-hundred-meter Aperture Spherical Radio Telescope is a sensitive listening device

An alien discovery

How the detection of a signal might change life on Earth

Politics

There will be discussions on how humanity should be represented – if we even respond.



Religion

Some religions may deny the discovery. Others may embrace it within their beliefs.



Culture

Discovering that we are not the only life in the universe would likely have a large impact on our culture.



Science

Perhaps the message would contain explanations of advanced scientific concepts, furthering our knowledge.

Conspiracies

If people can believe the Moon landings were faked, you can be sure some will not believe this news either.



How do we know if we've made contact?

Gerry Harp, director of the Center for SETI Research, reveals what we would expect to see



What are we looking for?

We're looking for signals that are clearly artificial. We have lots of ways we communicate using radio on Earth, and in principle ET might use the same. But the interstellar medium – the gas between stars – messes up signals, so we look for narrow-frequency bandwidth signals.

How would we verify a signal is real?

The signal has to persist. You have to look away and back with telescopes several times, until there have been five cycles. This tells you if it really is from that direction in the sky, or just scattered radiation.

Have we ever had a promising signal?

There has only been one that passed all our automated testing. That was in 2015, and it was exciting. We're always very sceptical, but we took a look and it was a very interesting signal almost designed to fool our system. It had all the right properties to look like something from outer space, but it was interference.

Our signals into space

The primitive attempts we've made so far to initiate contact

Cosmic Call 1

Sent: 1999

Sent by: Yevpatoria RT-70 telescope

Sent from a radio telescope in Crimea, the signal targeted four separate Sun-like star systems.

Teen Age Message

Sent: 2001

Sent by: Yevpatoria RT-70 telescope

Six Sun-like stars were targeted with a recording of a theremin – an early electronic musical instrument.

Cosmic Call 2

Sent: 2003

Sent by: Yevpatoria RT-70 telescope

The second phase of Cosmic Call transmitted photos and multimedia files to five stars.

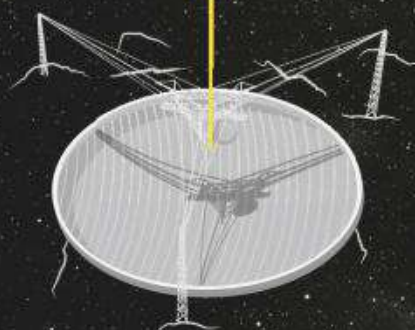


A Message From Earth

Sent: 2008

Sent by: Yevpatoria RT-70 telescope

A signal was sent to the exoplanet Gliese 581c, which is 20 light years from Earth.

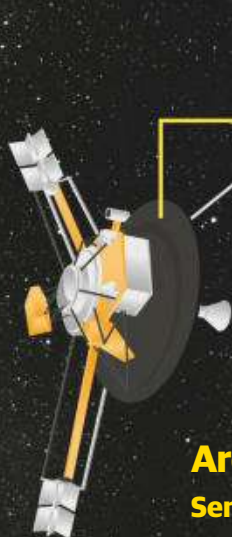


Pioneer plaques

Sent: 1972/1973

Sent by: Pioneer 10 and 11

The twin Pioneer spacecraft carried a pair of plaques with information about humanity.



Arecibo message

Sent: 1974

Sent by: Arecibo radio telescope

A 210-byte image detailing numbers, the chemistry of DNA, the shape of humanity and the Solar System.

Golden Record

Sent: 1977

Sent by: Voyager 1 and 2

The two Voyager craft have a vinyl record on board with sounds and images of Earth.



Across the Universe

Sent: 2008

Sent by: Deep Space Network

The Beatles' song *Across the Universe* was sent by NASA towards Polaris, some 430 light years away.

RuBisCo Stars

Sent: 2009

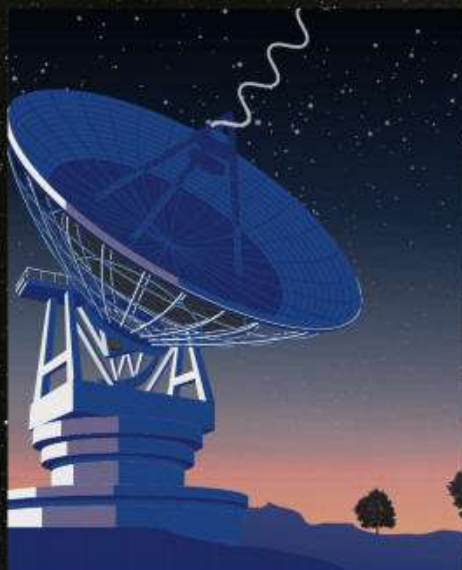
Sent by: Yevpatoria Deep Space Network

The genetic code for a protein involved in photosynthesis was sent to three stars.



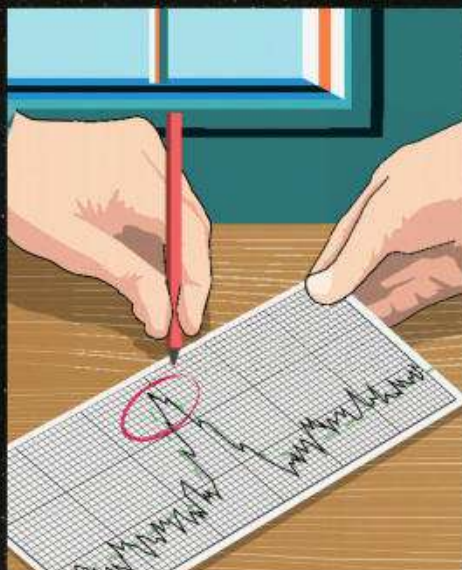
In the event of alien contact

Certain protocols have been drawn up by the SETI Institute for if an intelligent signal is found



1 Verification

While the discovery of a signal will be exciting, the first step is to make sure that the signal is real, and not from Earth-based interference. To do this the discoverer must repeatedly observe the signal five times, and rule out other sources like satellites or terrestrial radio waves. If the signal is continuously seen from the same region of sky when observing from different locations, then the discoverer can move onto the next step.



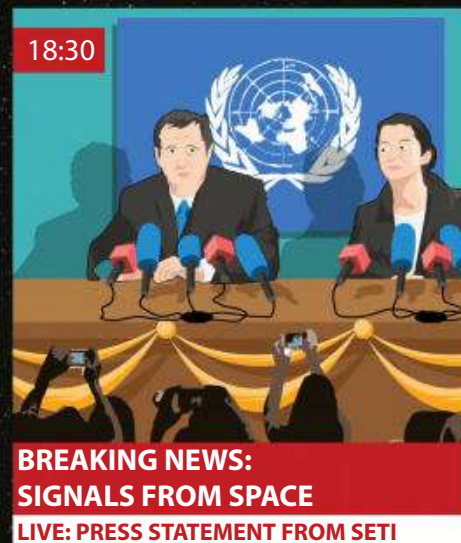
2 Get help

The discoverer now needs to inform other international observatories and institutions about the discovery. These need to all independently confirm the discovery themselves, and again verify that the signal is coming from another star, and not some sort of terrestrial interference. At this point there should not yet be a formal public announcement, but national authorities should be informed of the discovery.



3 Prepare the world

Now it's time to tell some of the bigwigs, who can prepare public announcements. The discoverer needs to open the findings to all observers around the world and reveal the discovery to the secretary-general of the UN. SETI then lists the institutions who should be informed, such as the International Telecommunication Union, the International Astronautical Federation and the International Institute of Space Law.



4 Tell everyone

Now it's time to publicly release the find. It should be noted that the discovery is already likely to have been leaked to the media through one form or another. Nonetheless, this is the formal point where the public can be told everything. The discoverer should be given the privilege of making the announcement. They've just made the most important discovery in history - they should get some recognition for it!



5 Release and record

All data from the signal - absolutely everything - should now be collected, recorded and stored permanently without any chance of any of the data being lost. All of this data should be given to the aforementioned international institutes, among others, and also released to the wider scientific community so that people can begin studying the signal in earnest. It's likely that by this point there would be a global race to be the first to decipher the message.



6 Block the frequency

Assuming the detection was made via electromagnetic signals, steps should be taken to block and protect the frequency that the discovery was made on. This would stop other people from broadcasting on it while discussions were held across the world about what to do next. It's not entirely clear how this frequency will be blocked, but SETI recommends "convening an Extraordinary Administrative Radio Conference" to make the necessary arrangements.



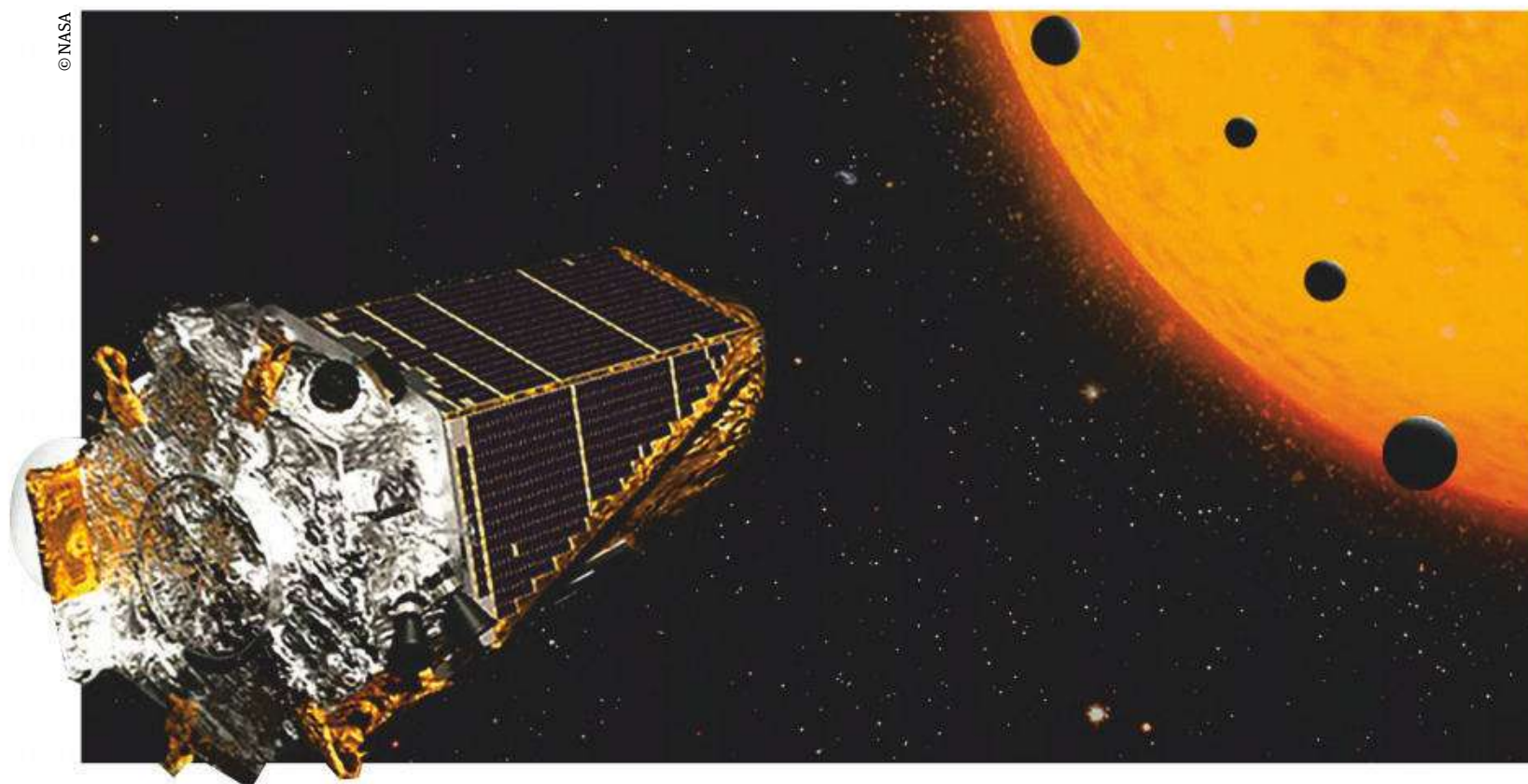
7 Consider a response

The world will now be debating whether to send a response or not, so SETI recommends that international talks should begin. Stephen Hawking argued against responding in case the aliens are hostile, but there are many who will want to reply. After all, what's the point in making contact if we aren't going to respond? The distances involved will likely be so large that any conversation will take place across generations, with little hope of either race visiting the other.



8 The aftermath

The final step is to create an international committee to serve as the main focal point for the analysis of the signal. This will include experts from around the world and "such other members as the committee may deem necessary," according to SETI. As for SETI itself, the signal would turn it from a fringe science into the most popular activity on Earth. Huge amounts of money would likely be poured into the endeavour to study this signal, and perhaps find alien life.



© NASA

know if somebody's out there. We hope they are. And you shouldn't stay silent when you see the evidence. It just doesn't sit right for me."

One group also in this camp is METI (Messaging Extraterrestrial Intelligence) International, who think we should be constantly sending out directed messages in the hope of a response, rather than waiting on the off chance that we hear something. "If we began transmitting to nearby stars in earnest, targeting all the stars within 50 light years from Earth and waiting for a reply, 100 years from now we could be hearing back from any of a couple of thousand stars whose inhabitants had received our signal," Douglas Vakoch, president of METI, tells **All About Space**.

But if an attempt at two-way communication is made, the distance of the planet will dictate what sort of conversation we can have. If it's nearby, within 50 light years, we could talk over generations. If it is much further, into the thousands of light years, then messages would only be sent back and forth over millennia. Maybe the messages would develop a sort of grand religion around them as people waited eons for a response. "Perhaps there would be little cults or something," says Harp.

But then what? The question of whether we are alone is arguably one of the greatest unsolved mysteries, and the impact of an answer would be far-reaching. Perhaps it would change life as we know it forever, or perhaps it wouldn't change much at all. We've got no way of knowing for sure. As for SETI itself, it would turn from a fringe science into the hottest subject on Earth. "The detection would be like winning the lottery," says Harp. "But there's a good chance it would destroy the SETI Institute, and other scientific institutions [would take over]."

But despite evidence suggesting there should be plenty of habitable worlds out there, we still haven't heard anything. Maybe the route to evolving into sentient beings is tough, and others haven't done it yet. Earth has actually formed relatively early in the universe - about 10 billion years into its existence - if you consider the universe will stick around for a few trillion years. That's not to say there isn't something out there, though. "Making contact is incredibly likely," says Elliott. "There are many places that could support life, even in our own Solar System. Not intelligent life, but life nonetheless." Maybe we just haven't looked hard enough yet. There could be others out there either waiting to hear from us, or looking on until we reach a more technically advanced stage.

But maybe we truly are alone. Considering the numbers that seems unlikely, and it's not an opinion widely shared in SETI circles. "I used to be a lot more confident there was something out there," says Harp. "I would say that in 100 years we could start examining a fair fraction of the galaxy with bigger and better radio telescopes. And if we don't find intelligent life we will have to start looking in other galaxies. It would be disappointing, but I think we'll know a lot more by then." It's easy to be optimistic, though. Surely there's someone else out there... and when we find them, we'd better be ready.

Above: NASA's Kepler space telescope has revealed far more exoplanets than we thought possible

"RED DWARFS MAKE UP 80 PER CENT OF THE STARS IN THE SKY, AND THEY LOOK LIKE THEY MIGHT BE HABITABLE TO LIFE"

When will we make contact?

2030

Douglas Vakoch

METI International

"My best guess for when we'll detect extraterrestrial life - if, in fact, we make contact in my lifetime - is by 2030, a decade from now."



2040

Seth Shostak

SETI Institute

"I've bet everyone a cup of coffee that we'll find a signal within two decades. If not, I'll have the opportunity to buy a lot of brew."



2050

John Elliott

UK SETI Research Network

"In 30 years I think we'll have the dish capacity, techniques and computing power, as well as the knowledge of where is best to target."



2070

Andrew Siemion

Berkeley SETI Research Center

"If we haven't detected evidence of intelligent life beyond Earth in 50 years, it is likely that we are essentially alone in the visible universe."



2120

Gerald Harp

Berkeley SETI Research Center

"My firm prediction is 100 years from now. I'm very confident, since I will be dead by then."



SUBSCRIBE

to **All About Space** and get a

LIMITED-EDITION

APOLLO 11 DIE-CAST MODEL

Apollo 11
lunar lander

Apollo 11
Command
and Service
Module

Worth
£12.99
each

CORGI

Choose either the Apollo 11 lunar lander
or the Apollo 11 Command and Service Module

Subscribe by 10 September for our exclusive offer



NEW!

Reasons to subscribe...

- You'll never miss an issue!
- It's delivered direct to your door
- Brilliant value – great savings on the cover price
- Special subscriber covers



Subscribe now

www.myfavouritemagazines.co.uk/aas/aas107
or call 0344 848 2852 and quote AAS107



£21.25
SAVING 37%

PRINT

Six-month subscription to All About Space in print plus one Apollo 11 die-cast model



£23.75
SAVING 60%

PRINT & DIGITAL

Six-month subscription to All About Space in print and digital plus one Apollo 11 die-cast model



*Terms and conditions: This offer entitles new UK Direct Debit subscribers to pay just £21.25 every six months, plus receive a choice of die-cast model. Gift is only available for new UK subscribers. Gift is subject to availability. Please allow up to 60 days for the delivery of your gift. In the event of stocks being exhausted we reserve the right to replace with items of similar value. Prices and savings quoted are compared to buying full-priced print issues (£5.20) and digital issues (£3.99). You will receive 13 issues in a year. Your subscription is for the minimum term specified. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) or are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magterms. Offer ends 10 September 2020

SHOOTING FOR THE MOON

HOW NASA TRAINED ITS APOLLO ASTRONAUTS



From battling river rapids and weathering sandstorms to scaling walls and flying spacecraft propelled at eye-watering speeds, preparing to be the first on the lunar surface wasn't for the faint-hearted

Reported by Gemma Lavender

Left: Three months after this photograph was taken, Armstrong was walking across the Moon



Shooting for the Moon



Above: Apollo 11's Neil Armstrong and Buzz Aldrin are given instructions before their Extravehicular Activity (EVA) training

We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard," the 35th president of the United States John F. Kennedy said resolutely to a large crowd that had gathered around his podium at Rice University Stadium in Houston, Texas, on 12 September 1962. That day the politician had laid down a gauntlet to NASA. The space agency's job was to find astronauts with the right stuff. Fortunately for NASA, the US wasn't short of citizens wanting to step up to the challenge.

One of the first candidates came in the form of a tall former pilot of the US Navy. An individual who had seen action in the Korean War - flying 78 missions for a total of 121 hours - and later became an experimental research test pilot. He went by the name of Neil Armstrong.

To NASA, Armstrong was the perfect fit; the space agency had decided that some experience of flying jets was indeed much more valuable than any kind of scientific training. There were also time constraints, meaning that the team who would later land on the Moon in July 1969 would need

to come well-equipped with experience. Naturally NASA looked to the Navy and Air Force to make their selections, but it turned out that Armstrong - who was chosen as a candidate in 1962 - became the only successful civilian candidate. His future crewmates Edwin 'Buzz' Aldrin and Michael Collins would be selected the following year, fresh from the Air Force and raring to go, their flight capability backed up with degrees in aeronautical engineering and science.

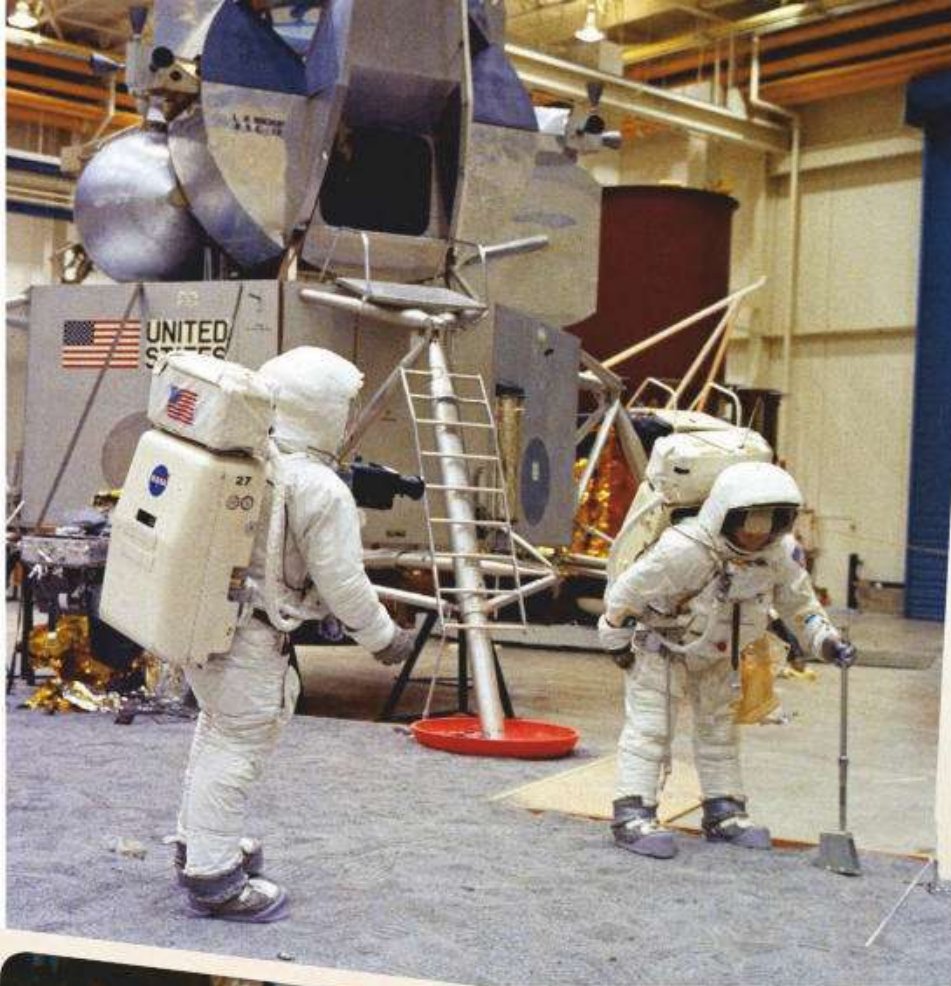
Crew assignment for the future lunar missions was announced on 20 November 1967 - a year before Apollo 8 would orbit the Moon and return safely. The aim of Apollo 8, Apollo 9 and Apollo 10 was to swing into lunar orbit and test every aspect of hardware that would make a future landing

"THE SPACE AGENCY HAD DECIDED THAT SOME EXPERIENCE OF FLYING JETS WAS MUCH MORE VALUABLE THAN SCIENTIFIC TRAINING"

possible. When it came to training, the tasks laid out before Armstrong, Aldrin and Collins were no different: every day, hour, minute and second was a dress rehearsal in how to make that "one small step for [a] man, one giant leap for mankind" a reality.

There was a lot to do, and the aim of reaching the Moon before the Soviets added a lot of pressure. NASA had only completed its first spacewalk two years before crew assignment, when Ed White left the confines of Gemini 4 for a 23 minute float above the atmosphere. While the Gemini project paved the way for Apollo, reaching and then landing on the Moon was still a big step up.

The Apollo astronauts worked tirelessly for 16 hours on a daily basis. No stone was left unturned in simulating the spacecraft, conditions or



Left: Armstrong and Aldrin train on a fake lunar surface ahead of the historic lunar landing

Below: Every part of the mission was practised over and over to ensure that the astronauts were ready



environment the spacefarers would face - what's more there were fewer computers and technologies than those easily available at our fingertips today.

If you took a walk through the testing facilities at NASA back in the 1960s, they'd look quite primitive. If the space agency wanted to reduce gravity to the one-sixth you'd discover on the Moon, for example, it simply suspended its candidates on a steeply inclined wall, making them run, jump and walk along it. It's a far cry from today's jetliners that swoop in arcs, giving passengers the low-gravity experience for minutes at a time.

Despite the obvious restraints, the facilities looked the part. An Apollo lander, fashioned out of aluminium and with over 1,800 kilograms (4,000 pounds) of thrust generated by an electric engine, was born out of a collaboration between NASA and Bell Aerosystems. Surrounding it, fake Moon rocks littered the surface to accurately depict the landing site. Everything was accounted for, from Armstrong's attempts at piloting in preparation for the nail-biting, bumpy descent to the cratered, mountainous terrain to the planting of the US flag. Armstrong, given that he would be the commander

Apollo highlights: getting mission-ready

Planting flags and picking rocks

It was perhaps one of the most iconic moments of Apollo 11: Neil Armstrong planting the American flag into lunar soil. And he had to train for it in a simulated moonscape surrounded by 'lunar rocks'. It was also common practice for all Apollo astronauts to play pretend when it came to collecting samples!



Stepping onto the lunar surface

It was one small step for [a] man, one giant leap for mankind. Apollo 11 commander Neil Armstrong had to practise climbing up and down the ladder that led from the Lunar Module - dubbed Eagle - to the lunar surface repeatedly a week before he and his crew launched for the Moon.



Walking in reduced gravity

On the Moon astronauts experienced gravity that meant they 'weighed in' at one-sixth their weight. The best way to simulate the experience was for would-be spacefarers to move along a wall inside the hangar at NASA's Langley Research Center. It gave an insight into how fast they would be able to move.



Splashdown!

It's a tried-and-tested method that has served astronauts well. The Apollo spacecraft were designed to return to our home planet by making an almighty splash into the Earth's extensive oceans. Knowing what to expect meant that astronauts had to train in pools of water, swimming around model space capsules.



Simulating the perfect landing

Featuring a General Electric turbofan engine, a vehicle that represented the Lunar Module was thrust into the air and could reach elevations of up to 450 metres (1,500 feet) to replicate the Moon's low gravity, which is one-sixth that of Earth's.



Shooting for the Moon

of Apollo 11, had to practise his first step onto an 'alien surface' and climb back onto the lunar lander to mock up the return home. "I really don't have the foggiest idea of what I was doing," a puzzled Armstrong was quoted as saying after the simulation. "If I were simulating a mission phase, I would have the helmet on and suit pressurised."

The primary aim of Apollo 11 was to not only observe the Moon, but to collect samples of it for further analysis. For this part of the program, both Armstrong and Aldrin were led out to the Arizona desert. It's here that NASA and scientists from the United States Geological Survey, or USGS for short, had been blasting large craters into the dry surface. A perfect representation of the lunar terrain, as the pair of astronauts discovered on their tour of the arid location, the USGS taught them about geological features as they explored. On what seemed to be the perfect site, simulations and soil-sampling techniques were practised, with the astronauts donning replica spacesuits to create an authentic experience. Future Apollo astronauts,

namely James Irwin and David Scott of Apollo 15, returned here later to test out the first lunar rover.

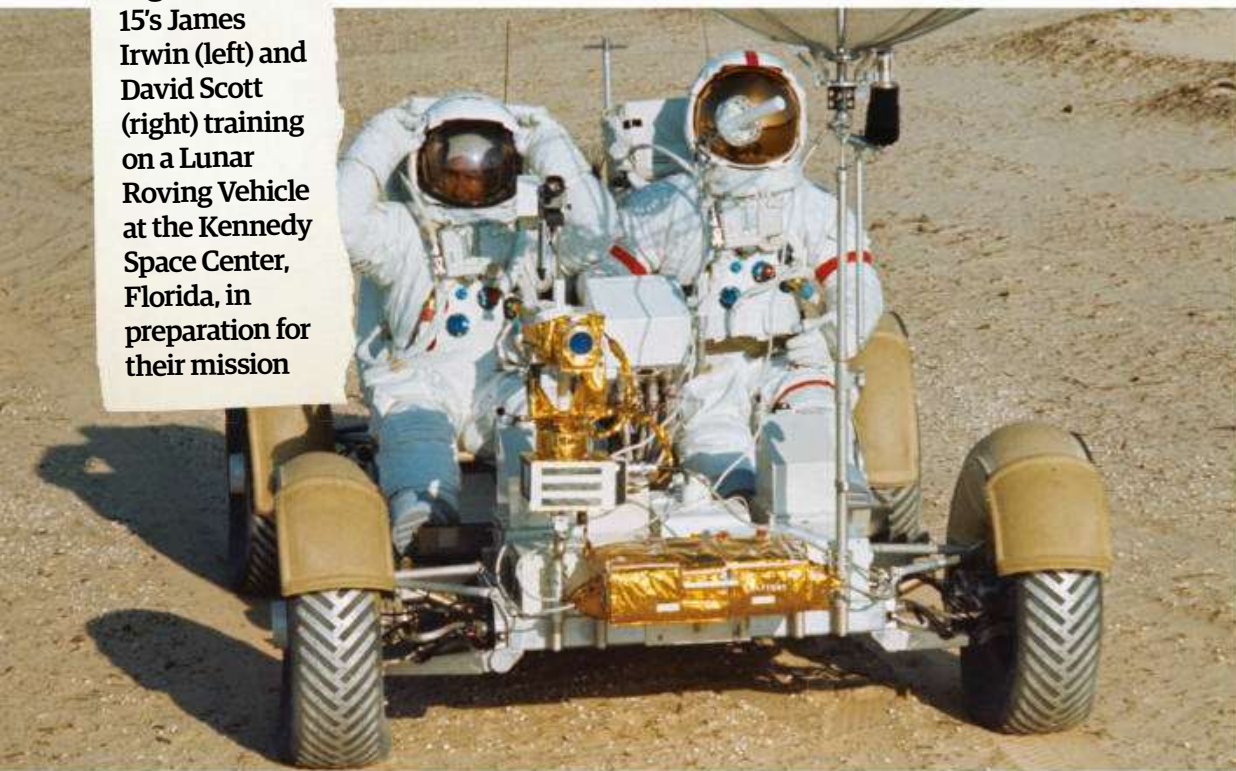
Getting to the lunar surface was just as important as the return home. It was intended that the astronauts would make a splashdown in the ocean. But what if the capsule missed its mark? According to NASA, there was every chance that the trio could have crash-landed thousands of miles off course, smashing through the leafy, warm and wet greenery of a jungle or smacking and sinking into the sands of a sweltering, hot desert. Wherever they ended up, they had to be prepared to survive the environmental extremes.

To prepare for such an occasion the astronauts were carted off to jungle survival school, located at Albrook Air Force Base in Panama, where they were tasked with anything from chopping down trees and foraging for food to making the most of leaves and branches to create lean-tos and tackling the challenging river rapids of the Panama Canal Zone. If the astronauts were extremely unlucky, they'd land in the desert. Stead Air Force Base

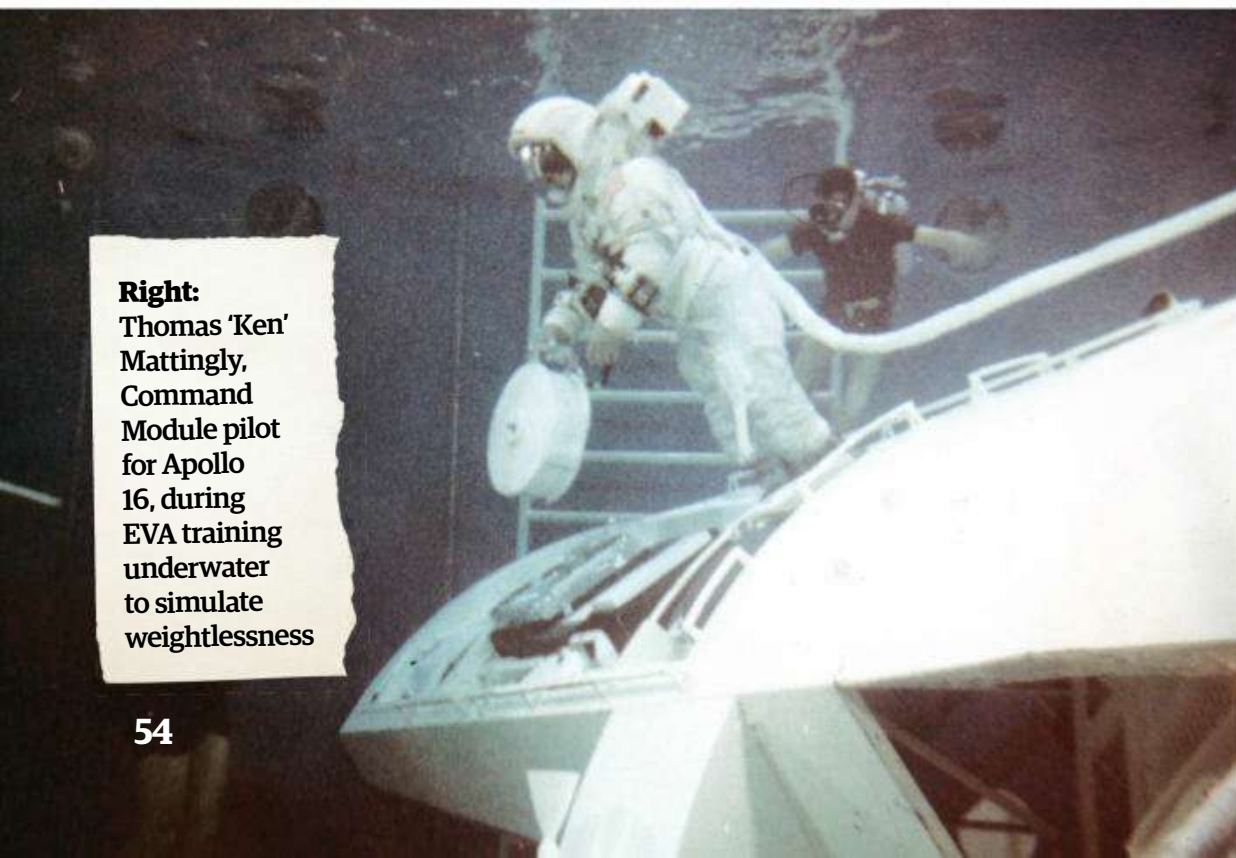
in Nevada suited their needs perfectly for tackling these complexities, being ideal for desert survival training. Apollo astronauts, even beyond the days of Apollo 11, were experts at creating makeshift shelters to weather sandstorms and steering clear of any desert wildlife perceived to be dangerous.

The relentless training Armstrong, Aldrin and Collins had endured might have been gruelling, but it helped them to make history on 20 July 1969. From the lunar surface, Aldrin stopped carrying out his experiments and answered a call. It was President Nixon, congratulating him and Armstrong on a successful landing. "All of us look forward to seeing you on the USS Hornet on Thursday," Nixon closed. Aldrin replied, "I look forward to that very much, sir."

Right: Apollo 15's James Irwin (left) and David Scott (right) training on a Lunar Roving Vehicle at the Kennedy Space Center, Florida, in preparation for their mission



Right: Thomas 'Ken' Mattingly, Command Module pilot for Apollo 16, during EVA training underwater to simulate weightlessness



Right: Apollo 15 commander David Scott training for an EVA in simulated low-gravity aboard the so-called 'vomit comet'



Above: Apollo 11 astronauts Armstrong and Aldrin rehearsing their EVA tasks on a simulated lunar surface



3 FREE DIGITAL BOOKS FOR EVERY READER!



60 SECOND SCIENCE

Discover **How It Works 60 Second Science**. In this fact-packed guide we introduce fundamental principles in physics, biology and chemistry with clear, concise explanations, infographics and illustrations. From the Big Bang to quantum mechanics and fossils to Wi-Fi, you'll be up to speed with the latest breakthroughs in no time. Throughout the book you'll also have the opportunity to put these theories into practice with our easy-to-follow experiments. See how circuits work with batteries made from lemons, detect Earth's magnetic field by making your own compass, learn how to instantly freeze water with a single touch and much more. What are you waiting for? Dive in to discover how the wonderful world around you works.

EVENTS THAT CHANGED THE WORLD

The Battle of Waterloo, Martin Luther King Jr.'s famous speech, 9/11 - there are some events in history that truly stand out as turning points. These changed politics, **civil rights, countries and continents**. They are the events that shaped our world. We explore these in detail here, from the inauguration of President George Washington in 1789 to the first atomic bomb - dropped on Hiroshima in 1945 causing unfathomable devastation - and beyond. Discover the events that led to World War I, the collapse of the Berlin Wall in 1989, the fight for women's suffrage and the presidency of Abraham Lincoln, plus the lasting legacy of these iconic moments. Together they form a turbulent story that is harrowing, sobering and inspiring in equal measure.

HISTORY OF NASA

On 29 July 1958 President Dwight D. Eisenhower signed into US law a federal statute that would change the universe forever. The National Aeronautics and Space Act led to the creation of a civilian space agency, one that was not controlled by generals, intelligence officials or businessmen, but by scientists. Its aim was not war, but peace. NASA was born. In the almost 62 years since its inception NASA has been responsible for some of the most important advances humankind has ever made. It has left the footprints of astronauts on our Moon and sent spacecraft beyond the limits of our Solar System. Its Mars rovers search for life on the plains of the Red Planet while Hubble looks back through time and space towards the beginning of the universe.

DOWNLOAD YOURS NOW AT: [SURVEYMONKEY.CO.UK/R/AAS_SEPTEMBER_EBOOKS](https://www.surveymonkey.co.uk/r/AAS_SEPTEMBER_EBOOKS)

Top-secret space shuttle

ON BOARD A TOP-SECRET SPACE SHUTTLE

An X-37B has been sent into orbit for its sixth mystery mission. **All About Space** uncovers what the ex-NASA spacecraft has really been up to

Reported by David Crookes

Top-secret space shuttle



Top-secret space shuttle

PLANNING A SECRET SPACE MISSION

AUGUST 1998

Boeing drop tests X-40A vehicle

Boeing creates the X-40A Space Maneuver Vehicle to 85 per cent scale and it is successfully drop tested, pleasing the US Air Force.

JULY 1999

NASA plans experimental space plane

NASA says it wants to build two vehicles, an Orbital Vehicle and an Approach and Landing Test Vehicle, as a test bed for new reusable rocket technologies.

MAY 2000

Test vehicle is delivered to NASA

With a \$173 million (£135 million) deal struck between NASA and Boeing, the X-37 project gets underway, based upon the earlier X-40A.

MAY 2001

Test flights are successful

Boeing announces its fifth straight flight of the X-40A Space Maneuver Vehicle, dropping it from a Chinook at 4,572 metres (15,000 feet).

NOVEMBER 2002

Boeing asked to complete X-37 development

NASA is impressed and awards Boeing the contract to continue development of the X-37 Approach and Landing Test Vehicle with a view to conduct atmospheric flight tests.

SEPTEMBER 2004

Project transferred to DARPA

NASA transfers the X-37 technology demonstration program to the Pentagon's DARPA. NASA says it will remain involved.



© NASA

There are many mysteries surrounding the nature of the universe. Why do pulsars pulse? What is dark matter? Is there life on Mars? But there are also some mind-bending teasers that have been created by humans which perplex even the greatest of minds. What, for instance, has the US military's unmanned X-37B space plane been up to during its numerous orbits of Earth? And why have the missions - including the most recent one launched in May this year - been shrouded in secrecy?

Few people outside the project know, and even fewer will give you the full lowdown on the true purpose of X-37B. This is a military mission, and most of the information about it is firmly classified. As such it has sent conspiracy theories into complete overdrive, especially since it is flying far in excess of the 270 days it was originally built for. Some say the craft is spying on other nations; others believe it could be a space bomber. The truth may well be much more mundane than that, but it is hugely fascinating nonetheless.

What we do know is that X-37B exists, and that aircraft and rockets with the 'X' designation have long been known to be experimental, high-speed vehicles. We also know what it looks like, what it contains and how it is powered. These are titbits of information which the military appears quite happy to discuss, but then that level of detail was already out there before the US Department of Defense took control of the project.

In 1999 NASA, Boeing and the US Air Force embarked on a \$173 million (£135 million) venture

to create a vehicle that could achieve orbit in outer space, collect test data in the Mach 25 re-entry region of flight and make autonomous landings. "We're going to do some missions in orbit, like rendezvous and station keeping," Boeing program manager David Manley told CNN in 1999. "On the second flight we plan to stay up there for almost three weeks and test some of our systems."

At that stage X-37 was to be a test bed for technologies such as thermal protection systems, storage and aerodynamic features for reusable space vehicles. NASA released an artist's impression of the space plane, shown to be far smaller than the Space Shuttle, with a payload bay that could be used for experiments. The space agency and its partners said they wanted the plane - dubbed the Orbital Test Vehicle (OTV) - to reduce launch costs by 90 per cent, making space transportation and operations much more affordable.

As well as experimenting with non-toxic liquid propellants, they also hoped that tests would result in safer and more reliable flights. However, in 2001 the project hit the rocks when the Air Force pulled its funding. Although the project went ahead anyway, with Boeing awarded a new \$301 million (£236 million) contract and asked to build two X-37 vehicles, one of which would be used in drop tests within the atmosphere, development ended up being pulled back two years later. NASA concluded that it wasn't sitting well with its agenda of space exploration, and so in 2004 it handed the project to the Defense Advanced Research Projects Agency (DARPA). It was then that the project became classified, so much so that NASA said it couldn't even name DARPA to the public. It only did so when it was given permission a couple of days later.

Below: After the third OTV mission, the X-37B lands having conducted experiments for 674 days

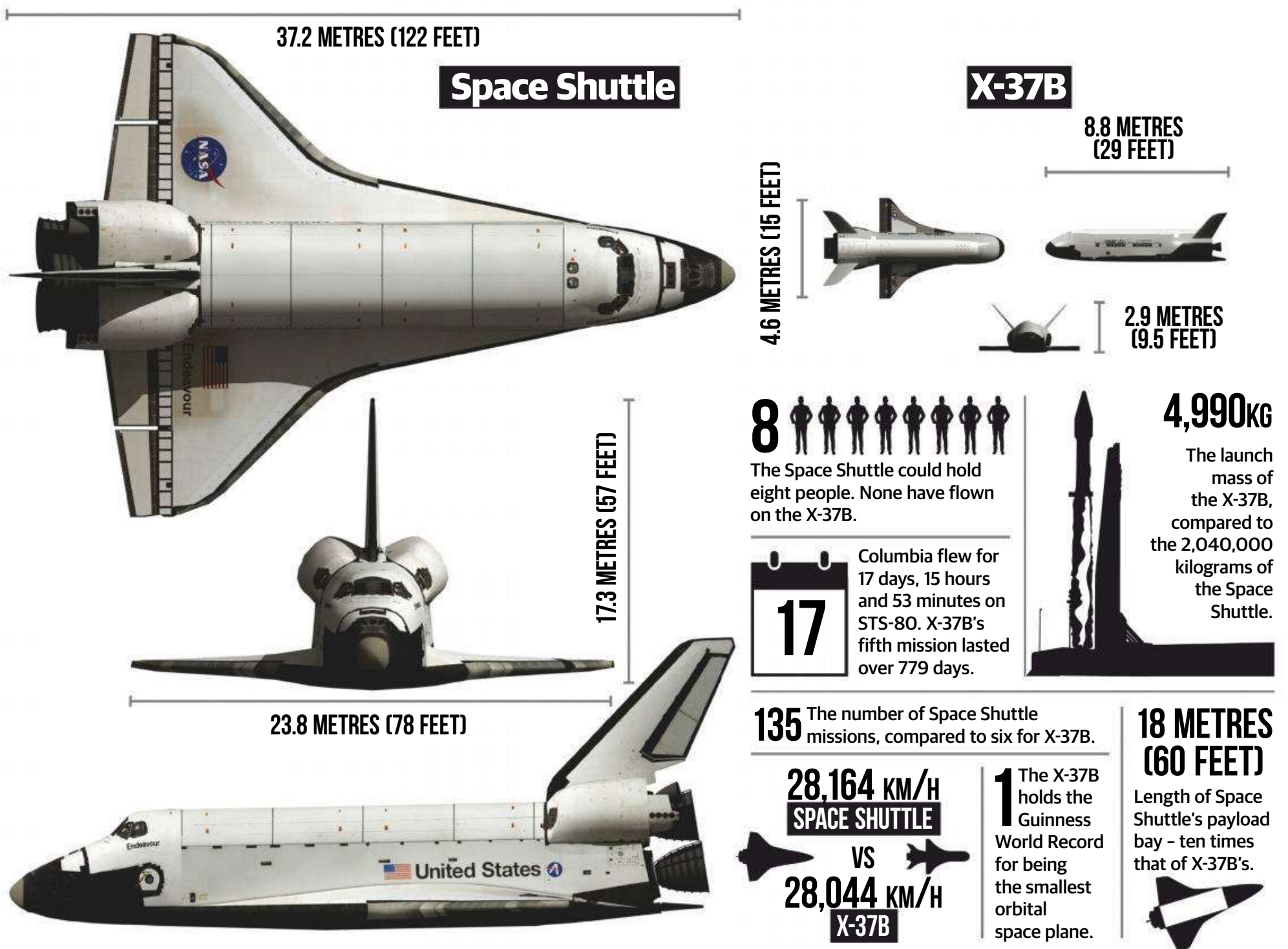


© Boeing

© NASA

US AIR FORCE X-37B VS NASA SPACE SHUTTLE

It's seen as a miniature version of an iconic spacecraft, but how does the X-37B really measure up?



But why did the department take over? "During the years when Donald Rumsfeld was secretary of defense, the Pentagon was pushed to move from thinking in terms of platforms such as ships, planes and tanks to capabilities," reckons Joan Johnson-Freese, a professor at the US Naval War College in Newport, Rhode Island, indicating that the military saw the potential possibilities on offer. "The more capabilities a technology or piece of equipment could deliver, the higher its overall value."

With the days of full openness about the project coming to an end, speculation began to mount. But it wasn't surprising. "I think the secrecy is routine," says physicist Mark Gubrud of the peace, war and defense curriculum at the University of North

Carolina. "Once it's been decided that something is classified, they carry out that policy." And yet interestingly, they didn't go down the path of a blanket ban on all information.

"They do announce the launches, which are observed from the ground and tracked by amateurs," says Gubrud. DARPA, together with

the Space and Intelligence division of Boeing and NASA, has issued photos of X-37B, and in the early days it detailed drop tests - the act of raising the spacecraft to a certain altitude and then releasing it. They spoke of difficulties encountered during

testing of the in-flight characteristics, and they didn't hide its components, nor that it is powered by a single Aerojet engine with storable propellants. "But they've decided to keep the payloads secret," Gubrud adds. "That definitely indicates that the payloads have a national security purpose."

The first X-37B - OTV-1 - was launched atop an Atlas V on 22 April 2010. As expected, no details were forthcoming about its orbit or the experiments that had been packed into the payload bay. It led to speculation that it was perhaps being used as a spy satellite. Indeed, there is a wide agreement among experts that it is perhaps being used for some sort of secret reconnaissance. But the Pentagon has strongly denied suggestions that OTV-1 was being

Top-secret space shuttle



© US Air Force; Michael Stonecypher

NOVEMBER 2006 US Air Force announces X-37B

The US Air Force says it is going to develop its own variant of NASA's X-37 - the X-37B Orbital Test Vehicle.

OCTOBER 2008 Space plane takes priority

NASA is looking to launch its Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite, but X-37B is scheduled in to use the Atlas V rocket launcher instead.

APRIL 2010 First X-37B vehicle launch

X-37B OTV-1 is launched from Cape Canaveral and placed into low-Earth orbit for testing. It suffers a tyre blowout on landing in December.

MARCH 2011 Second X-37B gets its launch

OTV-2 launches for Earth orbit in 2011 with the remit of testing new space technologies. It ends up in orbit for over 468 days.

SEPTEMBER 2011 Boeing announces scaled-up X-37C

Planned to be between 165 and 180 per cent the size of the X-37B, it would be able to carry up to six passengers.

DECEMBER 2012 A third mission blasts off

Six months after OTV-2 lands, OTV-3 launches. It was in orbit for 674 days and 22 hours before landing back on Earth in October 2014.

© US Air Force



tested as a weapon, categorically stating that it was not supporting the development of space-based weapons. So what does the Pentagon say? Only that X-37B would demonstrate experiments and allow satellite sensors, subsystems, components and 'associated technologies' to fly to space and back.

"A lot of those technologies are probably dual-use in the sense that they have both military and non-military applications, but that's almost always the case for space technologies," says Brian Weeden, director of program planning for the non-profit Secure World Foundation. One thing's for sure: one mission has not been enough. A second X-37B took off from an Atlas V on 5 March 2011. While the first had spent 224 days, 9 hours and 24 minutes

in space, this one spent 468 days, 14 hours and 2 minutes in low-Earth orbit - surprising given that it was only built for 270 days travel. Again the payload was not revealed, although as with the first craft there was a folded solar panel in the payload bay that could be opened to power the space plane on its mission. On 11 December 2012 the first X-37B embarked on its second mission - the third mission in total. This time the US Air Force said it was being used as part of a learning process, building on the results of the first flight. This time it didn't make frequent orbital manoeuvres, so there was some sort of learning process going on. But to what aim?

"The X-37B is a technology test bed," says Johnson-Freese. "It likely wasn't designed with a

INSIDE A PRIVATE MISSION

TECH SPECS

Length: 8.8 metres (29 feet)

Wingspan: 4.6 metres (15 feet)

Launch weight: 5 tonnes

Operating altitude: 200 to 925 kilometres (124 to 575 miles)

Re-entry speed: Mach 25

1 The GPS system

There is a navigation and flight control system for orbital and atmospheric flight, which tests an autonomous guidance system for re-entry and landing.

2 Jet Propellant 8 kerosene fuel is on board.

4 Payload bay

Often compared to the size of a pickup truck bed, it can fit a small satellite.

3 The space plane is unmanned and operated robotically.



5 Advanced avionics

The craft boasts advanced avionics for function-performing systems such as communication and navigation. The craft is testing lightweight electromechanical flight systems.

6 It gains power from a deployable solar array.



© US Air Force

particular purpose in mind, but rather to test its feasible capabilities across a wide range of options. Clearly from the number of missions flown, the duration of the missions flown and the variety of speculated tasks it has carried out - including orbit changes and experiments carried on board that we know about - the Air Force is pushing the envelope to determine what the vehicle can do."

Then to the fourth mission, which launched on 20 May 2015 using the second X-37B vehicle. This time there seemed to be more information,



although the Air Force, which ran the program via its Rapid Capabilities Office, wouldn't confirm if the objects on board were the same as the previous missions. Conspiracy theories cropped up: did it take out satellites - we'd probably have found out soon enough if it did - or was it on surveillance?

What we know for certain is that it was being used to test the onboard 4.5-kilowatt Hall thrusters, which could allow for even longer flights. "This is a type of ion engine," explains Weeden, "and it is different from the typical rocket engines that use chemical propulsion." Why is this important though? "Chemical rocket engines typically need to carry significant amounts of one or two different fuels, which gives them significant thrust, but only

Top-secret space shuttle



© NASA

WHERE HAS IT BEEN ORBITING?

OTV-4 orbited Earth at an altitude of 318 kilometres (198 miles). It completed an orbit once every 90 minutes at a low inclination of 38 degrees.

© FreeVectorMaps.com



9 Hall-effect thruster

An advanced ion engine, called a Hall thruster, was the focus of the fourth X-37B space mission.

8 Hydrogen peroxide is a good propellant.

7 Thermal protection

Silica ceramic tiles are used to create the heat-resistant thermal protection system, shielding the craft from a harsh re-entry, but they are said to be different to those on the Space Shuttle.

WHERE IT LANDS

Previous missions have landed automatically at Vandenberg Air Force Base, California.



© FreeVectorMaps.com

ATLAS V BOOSTER

A OTV-2

B Payload fairing

C Forward load reactor

D Centaur

E RL 10A Centaur engine

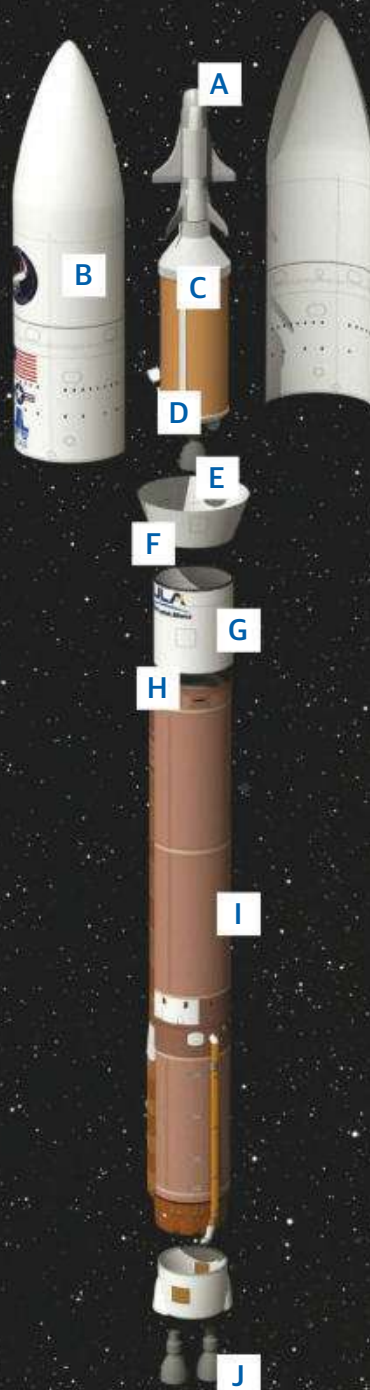
F Centaur Conical Interstage Adapter

G Centaur Interstage Adapter

H Cylindrical Interstage Adapter

I Atlas V booster

J RD-180 engine



The expendable Atlas V booster contains a Russian-built RD-180 engine - it burns kerosene and liquid oxygen to power the first stage and liquid hydrogen and liquid oxygen for the upper stage. It was used to launch the X-37B into space.

WHAT'S ON BOARD?

Hall ion-powered thruster

Hall thrusters are electric propulsion devices that create thrust by ionising and accelerating a noble gas. They offer better fuel economy and allow larger payloads and more on-orbit manoeuvring. This thruster is a modified version of those used on Advanced Extremely High Frequency military craft.

LightSail

The non-profit Planetary Society took advantage of the mission by hitching a ride, putting a small LightSail into Earth orbit. It carries four large, reflective sails that measure 32 square metres (344 square feet). Although too small to sail to the stars, the mirrored sails use the Sun's energy to generate momentum. Photons within the Sun's light push on the surface, lending a continuous thrust.

CubeSats

CubeSats are miniature research satellites, and as well as LightSail, X-37B deployed a further nine. Highly technical, they included a satellite researching the hosting of web servers on a CubeSat, one testing the on-orbit operation of a Micro-Cathode Arc Thruster and one demonstrating the use of the Globalstar constellation to control low-Earth orbit spacecraft.

NASA test equipment

A NASA experiment called Materials Exposure and Technology Innovation in Space exposed 100 different materials to the harsh environment of space. It is hoping to expand on the results gained by conducting a similar experiment on board the ISS, with some of the materials previously looked at being taken on board the space plane for testing.

A good dollop of mystery technology

As befits a mystery mission, there are bound to be other items on board the space plane, but official sources are not letting slip on further details. It is likely that whatever is on board will be tested for the effects of long-term exposure. The bonus of a spacecraft like this is that any objects that are sent up can be brought back down for further tests.

© Adrian Mann

Top-secret space shuttle

OCTOBER 2014 X-37Bs are moved to the Kennedy Space Center

The aircraft move to hangars previously occupied by the Space Shuttles.



MAY 2015 A fourth mission launches

The US Air Force launches a fourth mission, again from Cape Canaveral, which it says is to test the Hall-effect thruster and do scientific experiments.

SEPTEMBER 2017 Fifth flight of the X-37B

Launched using a SpaceX Falcon 9 instead of NASA's Atlas V as in all previous missions, the fifth mission lasts for 779 days, 17 hours and 51 minutes - the longest yet.

DECEMBER 2019 Space Force is formed

A new branch of the US military is formed. While the craft remain Air Force assets, Space Force is now responsible for launch, operations and landing.



MAY 2020 A sixth mission launches

The sixth mission launches from Cape Canaveral carrying the most experiments of any X-37B mission to date, including two by NASA.

MAY 2020 FalconSAT-8 released

The craft releases its satellite payload, FalconSAT-8, which carries five experiments. It will test an electromagnetic propulsion system, low-weight antenna technology and a commercial reaction wheel.



Above left:
The first X-37B vehicle in the encapsulation cell of the Evolved Expendable Launch Vehicle in 2010

Above right:
The White Knight jet-powered carrier aircraft launched the X-37A on test flights



"THERE IS A HIGH FEASIBILITY THAT THE X-37B CONTAINS INTELLIGENCE-GATHERING SENSORS SUCH AS RADAR, OPTICAL AND INFRARED"

BRIAN WEEDEN

for relatively short periods of time. Ion engines use a very small amount of a noble gas, such as xenon, and electricity to accelerate that gas to very high speeds," Weeden adds. "The result is a lot less 'oomph', but much more efficient thrust that can last for a much longer period of time. It's similar to comparing a race car that can go really fast for a few laps to a solar-powered electric car that takes a long time to get up to speed but can keep going for a long, long time."

With a fifth flight launched by a SpaceX Falcon 9 on 7 September 2017 and the latest on 17 May this year - reverting back to an Atlas V - these missions are likely to continue testing advanced guidance, navigation and control; avionics; high-temperature structures and seals; lightweight electromechanical flight systems; advanced propulsion systems; thermal protection systems and the autonomous methods of orbital flight, re-entry and landing - all things that the project managers have stated it is doing without delving into very much detail.

Does that completely rule out that it could be a space bomber, though? "I do not believe that X-37B is well adapted for any role as a space weapon," says Gubrud. "Its re-entry tiles, wings and landing gear are just dead weight if you are using it to manoeuvre and attack in space or even just inspect

foreign satellites. Nor is it likely to be feasible to grab adversary satellites and bring them down using the X-37B. It is too small and not equipped with robotic tools that would be needed to grab and secure a satellite and trim off its antennae, solar panels and so on to fit it and secure it in the small cargo bay."

So no part could be for military use? "Since the overwhelming amount of space technology is dual-use, certainly some of those capabilities could be considered weapons-related, if only peripherally," says Johnson-Freese. Mystery once more, but ion engines certainly aren't unique to the military - many satellites use them today. However, as Weeden says, there is a high feasibility that the X-37B contains intelligence-gathering sensors such as radar, optical and infrared, and that the thrusters will allow for the development of lighter low-orbit satellites that could take better ground images. "My guess is that they include some classified sensor technologies for remote sensing," he explains. "That could include optical imaging sensors, although given the orbit of the X-37B, it's more likely to be radar imagers or signals intelligence sensors."

We can't say whether or not we will ever truly discover all that is on board X-37B. Neither do we know everything it has been doing in the time that it has been in orbit across six flights. One thing's for sure though: those out of the loop will be keeping a close eye on it for the foreseeable future.

FEED YOUR MIND

www.howitworksdaily.com



HOW IT WORKS™

Available
from all good
newsagents and
supermarkets

FEATURING NEW AUGMENTED REALITY EXPERIENCE!

SCIENCE UP CLOSE



INSIDE GADGETS



COOLEST TECH



ILLUSTRATIONS



AMAZING FACTS



BUY YOUR ISSUE TODAY

Print and digital subscriptions available at
www.myfavouritemagazines.co.uk

Available on the following platforms



facebook.com/howitworks



twitter.com/@howitworksmag

EXOPLANETS

How does a planet's colour influence its habitability?

Much like a white shirt keeping you cool on a bright summer day, a planet's colour plays an important role in keeping a planet's temperature just right for life. Our search for life is currently focused on finding exoplanets with temperatures in a range that allow for liquid surface water. An exoplanet with a dark surface like ocean or basalt will absorb a lot of the incoming stellar energy and heat up. A brighter surface like snow or sand will reflect stellar energy and prevent the temperature from rising.

Because colour plays such an important role in temperature, there are sweet spots in the interaction between type of starlight, exoplanet colour and exoplanet-star distance

© NASA/JPL-Caltech

that allow for liquid water to exist. Having a better understanding of this complex system of interactions will help us find a habitable planet.

In the coming decade we will be able to assess the habitability of exoplanets with direct measurements. Until then we need to model many different scenarios so we are prepared for a wide range of possible environments. By modelling the way exoplanet colour influences habitability, we can focus our search on the exoplanets that show the most promise for life. This gives us a way to compare real observations with the physics we expect.



Dr Jack Madden is an astrophysicist at Cornell University, New York

Above: Darker exoplanets typically absorb more heat than lighter reflective ones



Left: Asteroids can fragment from a parent body, but they no longer form via accretion

SOLAR SYSTEM

Could asteroids still be forming in the Solar System?

Originally asteroids formed in the early phases of the Solar System when the Sun was surrounded by a disc of gas and dust particles, which collided together to form larger bodies. These objects are the leftovers of the planetary building blocks that now mostly reside in the asteroid belt between Mars and Jupiter. There is no creation of asteroids by this mechanism anymore because the relative speeds between existing asteroids are too high; therefore when they collide with each other the outcome cannot be an accretion anymore, but rather a disruption.

However, collisions occurring between asteroids sometimes cause the disruption of a large asteroid. Asteroid families, which are identified groups of asteroids sharing the same orbital characteristics and composition, are evidence of such disruptions. Each family is the product of the disruption of a parent body, and family members are the fragments produced by such a disruption. In this sense asteroids are still forming as fragments of larger ones that are disrupted by a collision. In fact, based on our current understanding, most asteroids smaller than 50 kilometres (31 miles) in diameter are believed to be

at least of the second generation.

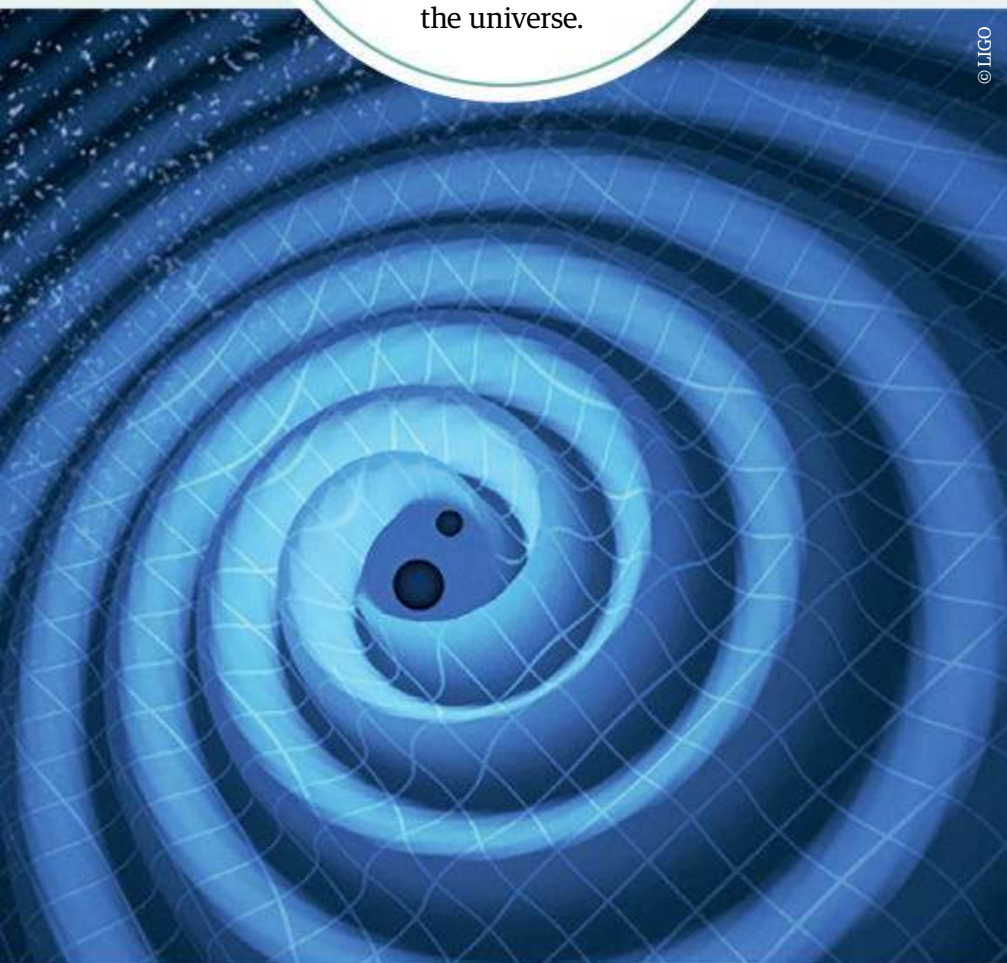


Dr Patrick Michel is the director of research at the French National Centre for Scientific Research

© NASA/JPL-Caltech

Did you know?

Gravitational waves are ripples in space-time caused by collisions of massive objects - like black holes - somewhere in the universe.



© LIGO

Left: The first gravitational wave detection occurred in 2015

ASTROPHYSICS

Do gravitational waves travel at the speed of light?

Gravitational waves should travel at the speed of light, but in science we can never truly say that two things are exactly the same. We can only compare our measurements and say how much room they have to possibly be different. In the case of light and gravitational waves, you want to have an event that gives off both at the same instant, and then measure when both signals arrive. If a light wave and a gravitational wave were to race to us from Proxima Centauri, the nearest star after the Sun - a distance of a little more than four light years away - they would arrive at the finish line within a few nanoseconds of each other. Perhaps even closer, but that's as good as our measurements have gotten up to now.

We think that gravitational waves should travel at the speed of light because that is what Einstein's theory of general relativity predicts. But Einstein may not be the final word on gravity - just as Newton's ideas on gravity had to be modified by Einstein. That's why we make measurements, to find out all the cool stuff our theories can't yet explain!

Dr Kathleen E. Saavik Ford is an astrophysicist at City University of New York Graduate Centre, the Borough of Manhattan Community College and the American Museum of Natural History



SPACE EXPLORATION

How does it feel to be in zero gravity for the first time?

There's no way to simulate weightlessness properly on Earth, and I learned a long time ago that all simulators are wrong. You have to remember that as a test pilot and as an astronaut. The simulator is just a way to get close enough to reality that hopefully you'll be able to deal with it in real life.

When you actually get to space and you unstrap from your chair and come floating up into weightlessness, it's permanent. It doesn't stop as soon as the aeroplane pulls out or as soon as your feet touch the ground. We're so used to being pulled down by gravity that it almost feels like you're being pulled up as you're so used to your hair being pushed down on your head. You are used to having the spit in your mouth at the bottom of your mouth, right? But suddenly when there is no gravity, everything feels like it's being pulled up towards the ceiling by invisible strings. It feels like instantaneous magic because suddenly you can tumble and float and fly. It's great!

Chris Hadfield is a retired Canadian astronaut and served as commander of the Space Station

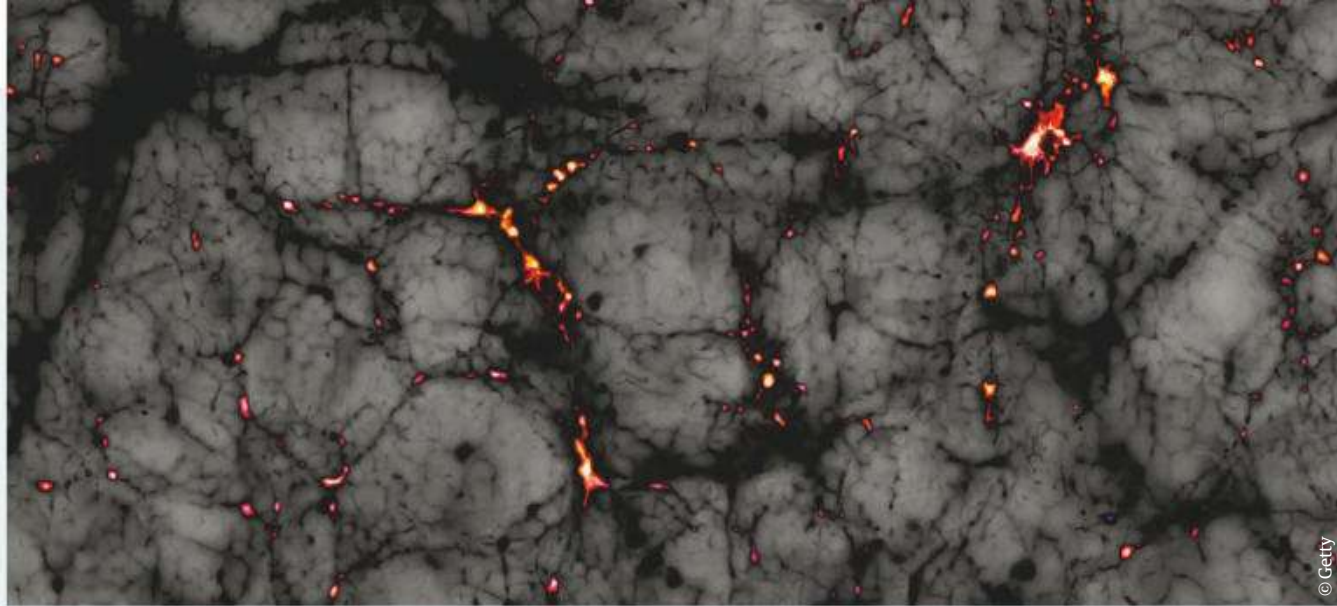


© NASA



© NASA

Right: If dark matter emitted light, it would no longer be dark



© Getty

COSMOLOGY

Can dark matter emit dark light?

We know little about the properties of dark matter. Various theories of dark matter, with or without dark light emission, have been proposed in the last few decades. Whether or not dark matter emits dark light is a key property that may allow us to pin down the theory of dark matter.

Theories of dark matter which emits dark light are constrained. In those theories dark matter interacts with itself by exchanging dark light. If the interaction occurs too frequently, the distribution of dark matter in galaxies becomes very different from what is inferred from the current observations of the gravitational potential made by dark matter. Recent studies show that if dark matter interacts with dark light with the same strength as protons do with ordinary light, dark matter must be more than a hundred times heavier than protons. The bound on the mass is weaker for weaker interactions. As long as this constraint is satisfied, dark matter can emit dark light. Dark light should be almost



invisible to us - otherwise dark matter is no longer dark.

Dr Keisuke Harigaya is a member of the School of Natural Sciences at the Institute for Advanced Study (IAS) at Princeton, New Jersey

ASTROPHYSICS

Why won't the Sun eventually become a neutron star?

Below: The Sun will eventually become a white dwarf and appear as a beautiful planetary nebula

Left: Hadfield participated in three spaceflights and two spacewalks

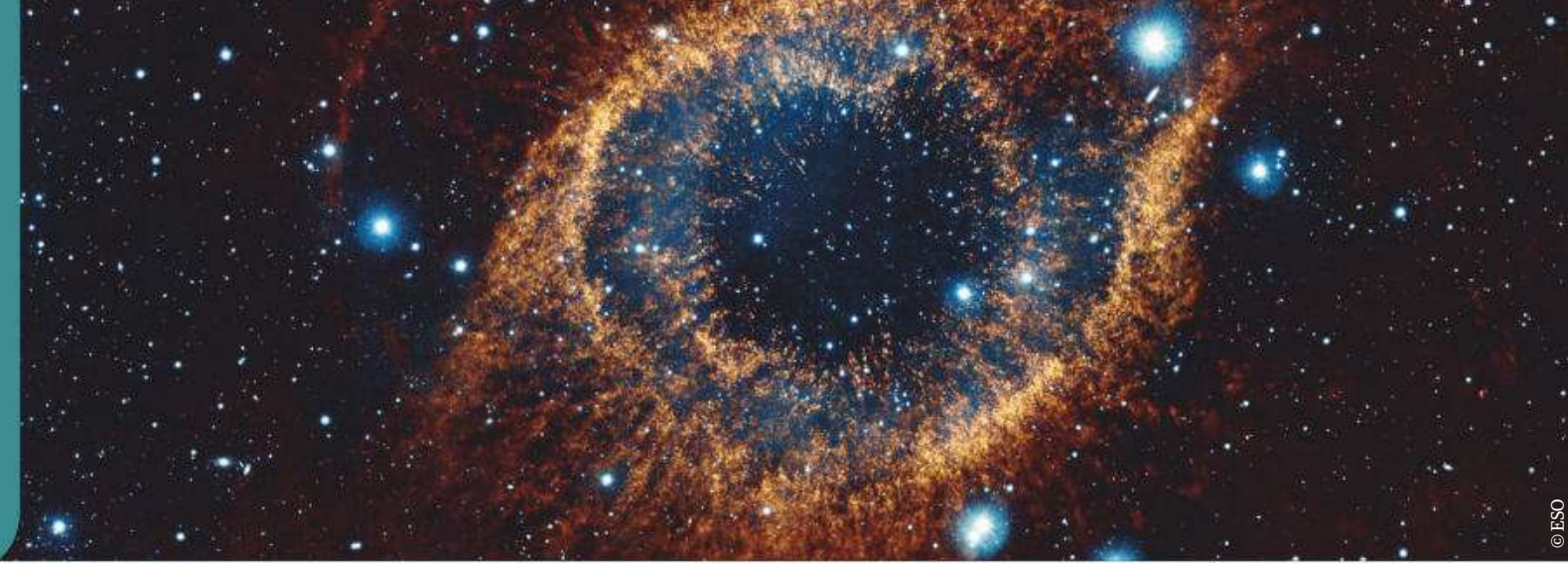
Neutron stars can only form after the explosive deaths of stars with masses between about eight and 25 times the mass of the Sun. In contrast, our star, after approaching the end of its life in approximately 5 billion years from now, will evolve through a series of expansions and contractions and will quietly transform into a very small and dense object known as a white dwarf.

This very compact object will contain approximately half of the Sun's mass densely packed in a sphere, with a diameter of roughly 10,000 kilometres (6,200 miles).

The other half of the Sun's mass - its outer layers - will be thrown into the surrounding environment, creating a so-called planetary nebula, a fascinating bubble of expanding and glowing gas. While the gas of the planetary nebula will disperse into space, disappearing within about 10,000 years, the white dwarf will keep shining for several thousand billion years before turning into a cold, dark, inert remnant known as a black dwarf.



Dr Mario Spera is a Marie Curie postdoctoral fellow at the University of Padova, Italy



© ESO

SOLAR SYSTEM

What are cryovolcanoes?

Volcanism, as it is most commonly known, involves the eruption of hot, molten rock or ash. However, numerous worlds in our Solar System exhibit icy volcanism, or cryovolcanism, during which cryogenic mixtures - for example a briny slush, ammonia-water slurries or a mélange of icy particles and water vapour - are erupted instead of molten rock.

In addition to shaping the surfaces of several moons in the outer Solar System, cryovolcanism has also played a role in sculpting the surfaces of dwarf planets Ceres and Pluto. Just as Earth's volcanoes are produced by the eruption and gradual build up of lava and ash, cryovolcanoes are produced in much the same way by the eruption of icy lava, or cryolava.

Dormant cryovolcanoes such as Ahuna Mons and Wright Mons have been imaged on Ceres and Pluto by NASA's Dawn and New Horizons spacecraft respectively. A subset of

domes on Jupiter's moon Europa may also be small cryovolcanoes.

At present, active cryovolcanism in our Solar System takes the form of the eruption of geyser-like plumes on the moons of Jupiter, Saturn and Neptune. NASA's Voyager 2 and Cassini spacecraft imaged geyser-like eruptions in the south polar regions of Neptune's moon Triton and Saturn's moon Enceladus respectively, while reanalysis of data from the Galileo spacecraft and observations by the Hubble Space Telescope and Keck Observatory reveal possible detections of geyser-like plumes on Jupiter's moon Europa. In addition, Triton, Europa and Titan show evidence of recently emplaced cryolava flows, suggesting that cryovolcanism manifests in a variety of ways on their surfaces.



Dr Lynnae C. Quick is an ocean worlds planetary scientist at Goddard Space Flight Center, Maryland

Below:
Voyager 2 saw geyser-like eruptions on Neptune's moon Triton

Did you know?

In 1801 Ceres was the first 'asteroid' to be discovered. It was reclassified as a dwarf planet along with Pluto in 2006.



STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

What's in the sky?

In this issue...

68 What's in the sky?

Even with NEOWISE dimming and the Perseids departing, there's still plenty to observe

76 Deep sky challenge

Glittering clusters, a dead star's corpse and a beautiful double star are on show

72 Month's planets

Gaseous duo Jupiter and Saturn still make a stunning pair before they dip below the horizon

78 The Northern Hemisphere

Aquarius and Pegasus grace the skies heading into September

74 Moon tour

To the south of Plato are mountains worth exploring with a telescope

80 Telescope review

We test the Sky-Watcher Explorer-130PS reflector

75 Naked eye and binocular targets

Meet some of the summer Milky Way's forgotten wonders

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

**13
AUG**



Venus reaches its greatest distance from the Sun (elongation), shining at -4.3

**13
AUG**



Globular cluster Messier 15 is well placed for observation in Pegasus at magnitude +6.3

**14
AUG**

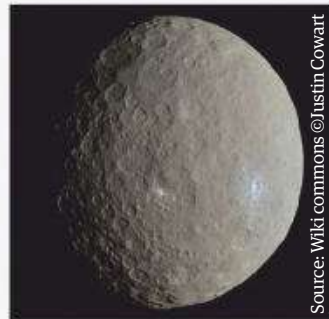


Globular cluster Messier 2 is well placed for observation in Aquarius at magnitude +6.6

**28
AUG**



Dwarf planet Ceres is well placed for observation in Aquarius at magnitude +7.7



Source: Wiki commons @Justin Cowart



©NASA/ESA

**6
SEP**



The Moon and Mars make a close approach, passing within 0°01' of each other in Pisces

**8
SEP**



Venus reaches its highest point in the morning sky, shining brightly at -4.3

**9
SEP**



The September Epsilon Perseids reach their peak of roughly five meteors per hour

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

Galaxies



© ESA/Hubble & NASA

**15
AUG**



The Moon and Venus make a close approach, passing within 3°59' of each other in Gemini

**17
AUG**



The Kappa Cygnids reach their peak of roughly three meteors per hour

**29
AUG**



The Moon, Jupiter and Saturn will make a close approach within 1°24' of each other in Sagittarius



© NASA

**29
AUG**



Asteroid 20 Massalia is at opposition and well placed for observation in Aquarius at +9.6

**31
AUG**



The Aurigid meteor shower reaches its peak of approximately six meteors per hour

**1
SEP**



Conjunction between Mars and dwarf planet Eris in Pisces and Cetus respectively

Source: Wiki commons ©Astronomical Institute of the Charles University: Josef Durech, Vojtěch Sidorin



Naked eye

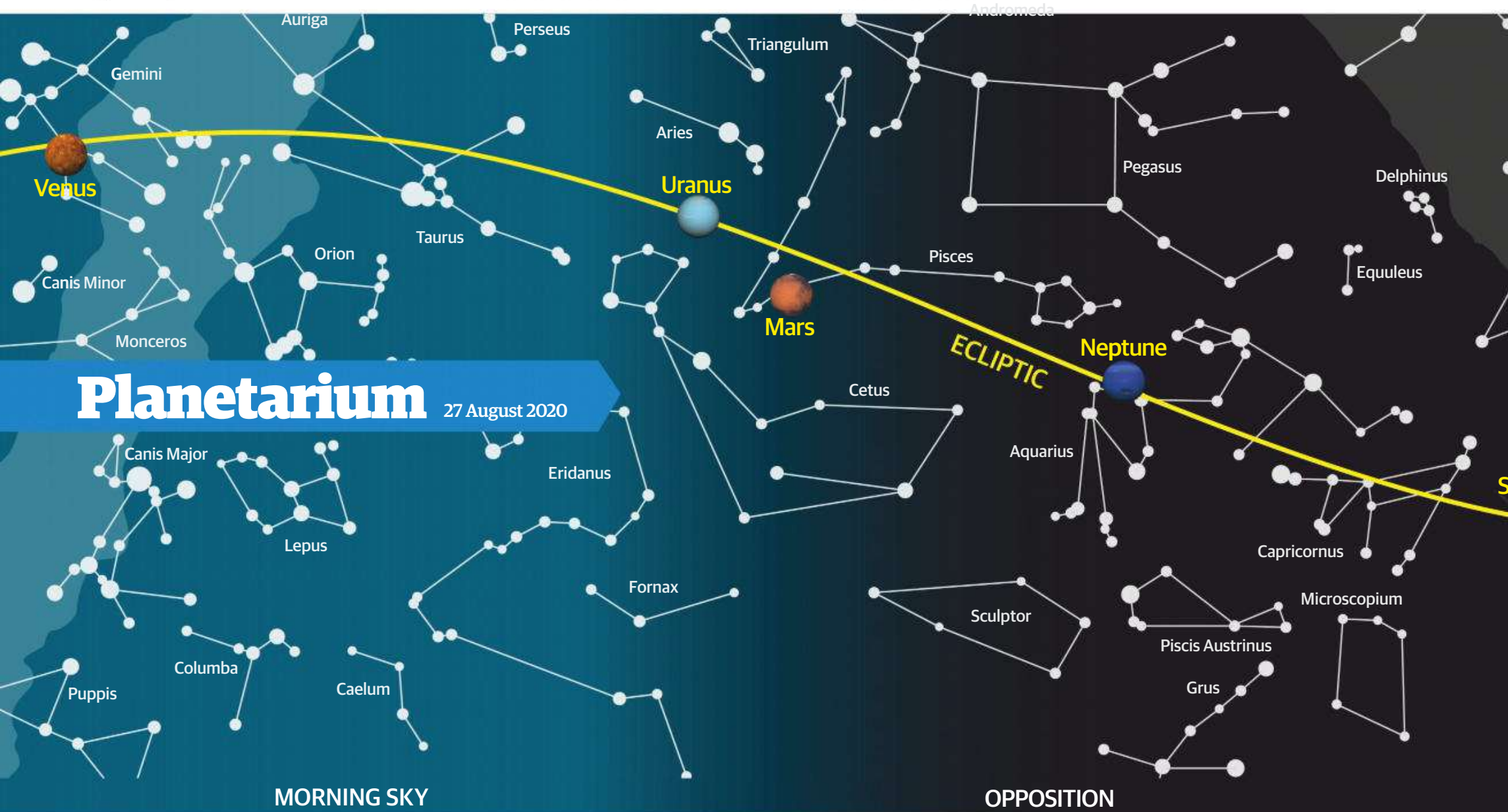
Binoculars

Small telescope

Medium telescope

Large telescope



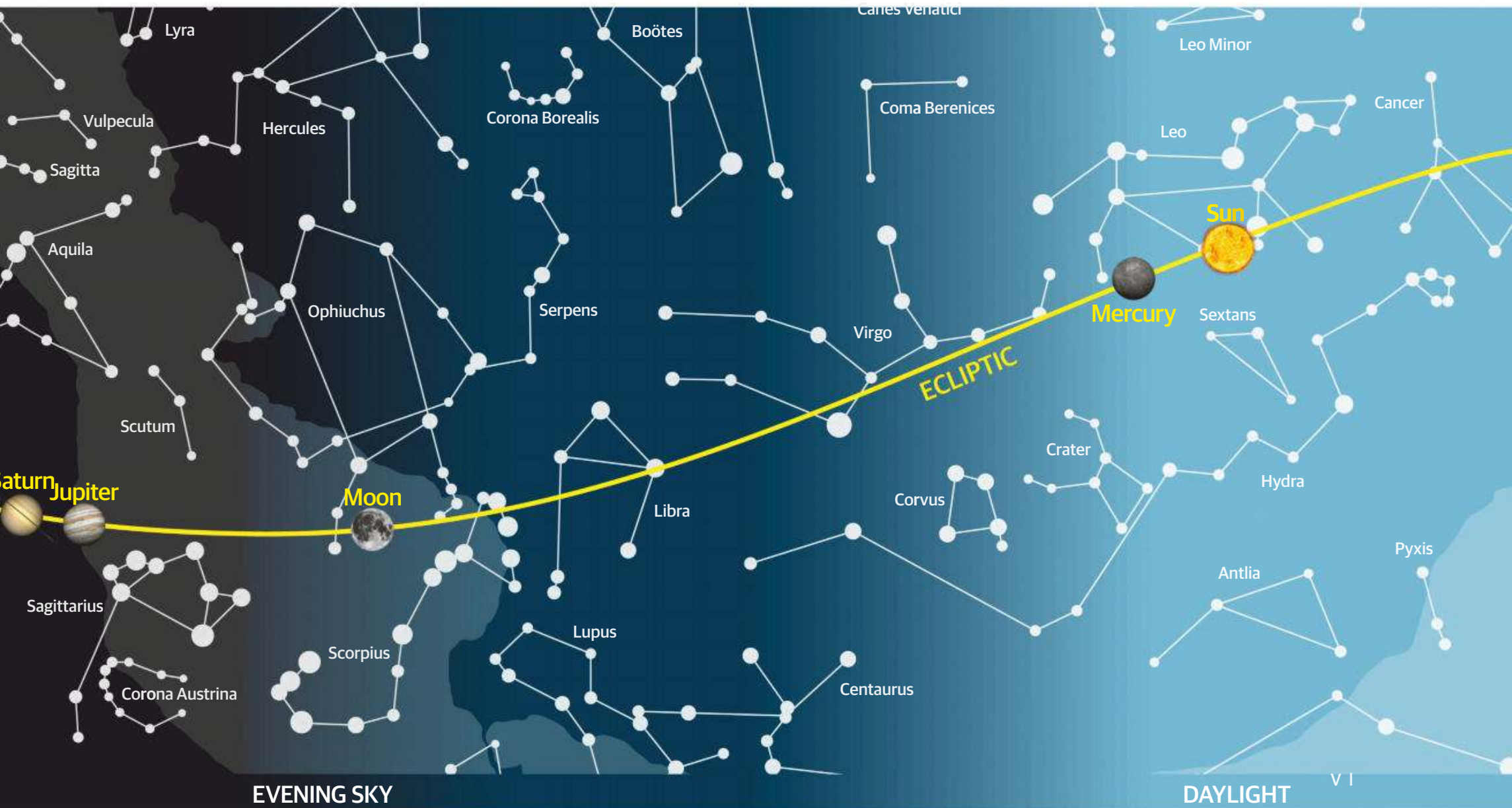


Moon calendar

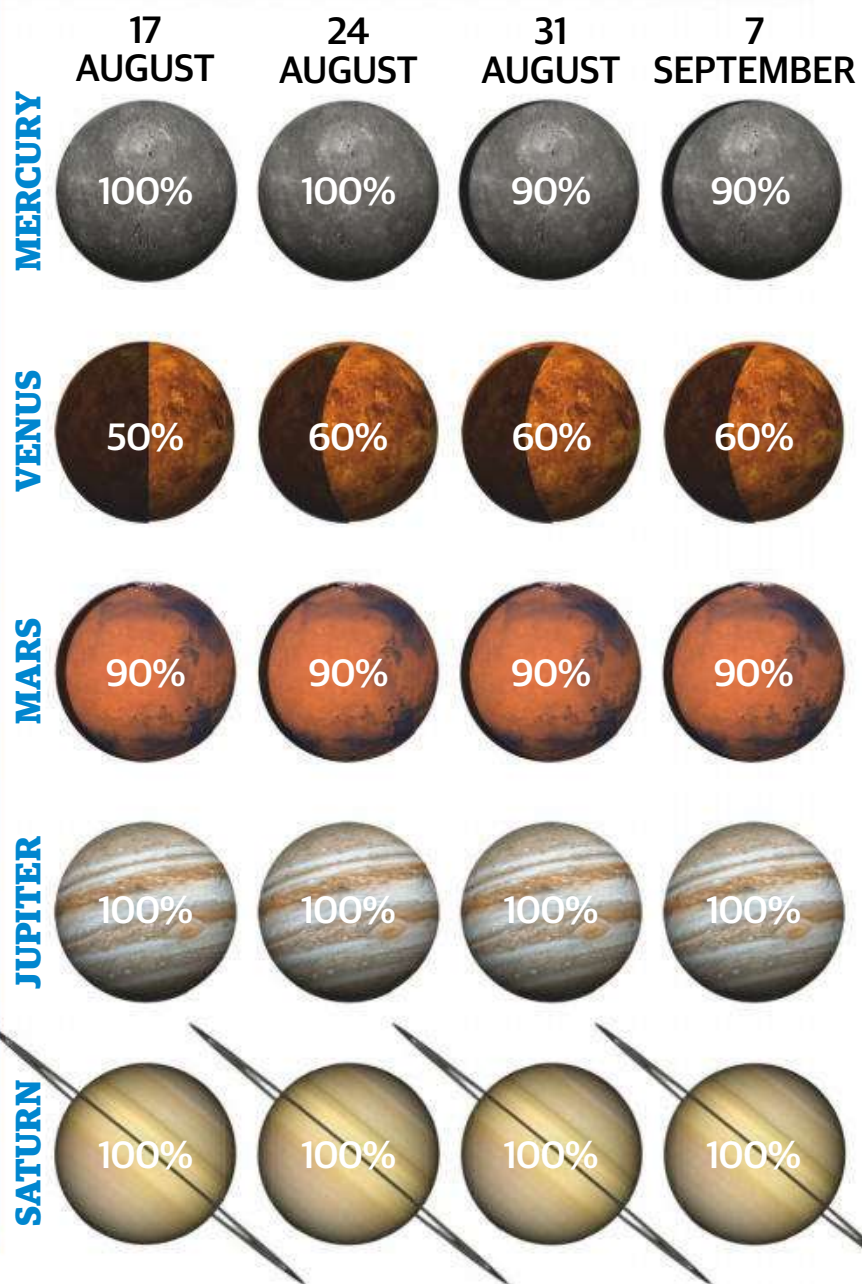
* The Moon does not pass the meridian on 31 August

13 AUG 34.9% ☀ 00:03 ☾ 16:12	14 AUG 25.3% ☀ 00:33 ☾ 17:19	15 AUG 16.6% ☀ 01:13 ☾ 18:20	16 AUG 9.3% ☀ 02:05 ☾ 19:13
17 AUG 3.7% ☀ 03:11 ☾ 19:55	18 AUG 0.7% ☀ 04:27 ☾ 20:29	19 AUG NM 0.4% ☀ 05:49 ☀ 20:56	20 AUG 3.2% ☀ 07:14 ☾ 21:19
21 AUG 8.8% ☀ 08:40 ☾ 21:39	22 AUG 17.0% ☀ 10:05 ☾ 21:59	23 AUG 27.1% ☀ 11:29 ☾ 22:19	24 AUG 38.3% ☀ 12:53 ☾ 22:43
25 AUG FQ 50.0% ☀ 14:15 ☾ 23:11	26 AUG 61.5% ☀ 15:33 ☾ 23:46	27 AUG 72.1% ☀ 16:45 ☾ ---	28 AUG 81.4% ☀ 00:31 ☀ 17:45
29 AUG 89.1%* ☀ 01:26 ☀ 18:34	30 AUG 94.7% ☀ 02:30 ☀ 19:11	31 AUG ---%* ☀ 03:40 ☀ 19:40	1 SEP 98.3% ☀ 04:51 ☾ 20:03
2 SEP FM 99.8% ☀ 06:02 ☀ 20:21	3 SEP 99.2% ☀ 07:12 ☀ 20:38	4 SEP 96.7% ☀ 08:20 ☀ 20:53	5 SEP 92.4% ☀ 09:27 ☀ 21:08
6 SEP 86.5% ☀ 10:34 ☀ 21:24	7 SEP TQ 79.2% ☀ 11:42 ☀ 21:42	8 SEP 70.9% ☀ 12:50 ☀ 22:03	9 SEP 61.6% ☀ 13:58 ☀ 22:30
10 SEP TQ 51.7% ☀ 15:05 ☀ 23:05	% Illumination ☀ Moonrise time ☾ Moonset time FM Full Moon NM New Moon FQ First quarter TQ Third quarter		

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

All rise and set times are given in BST

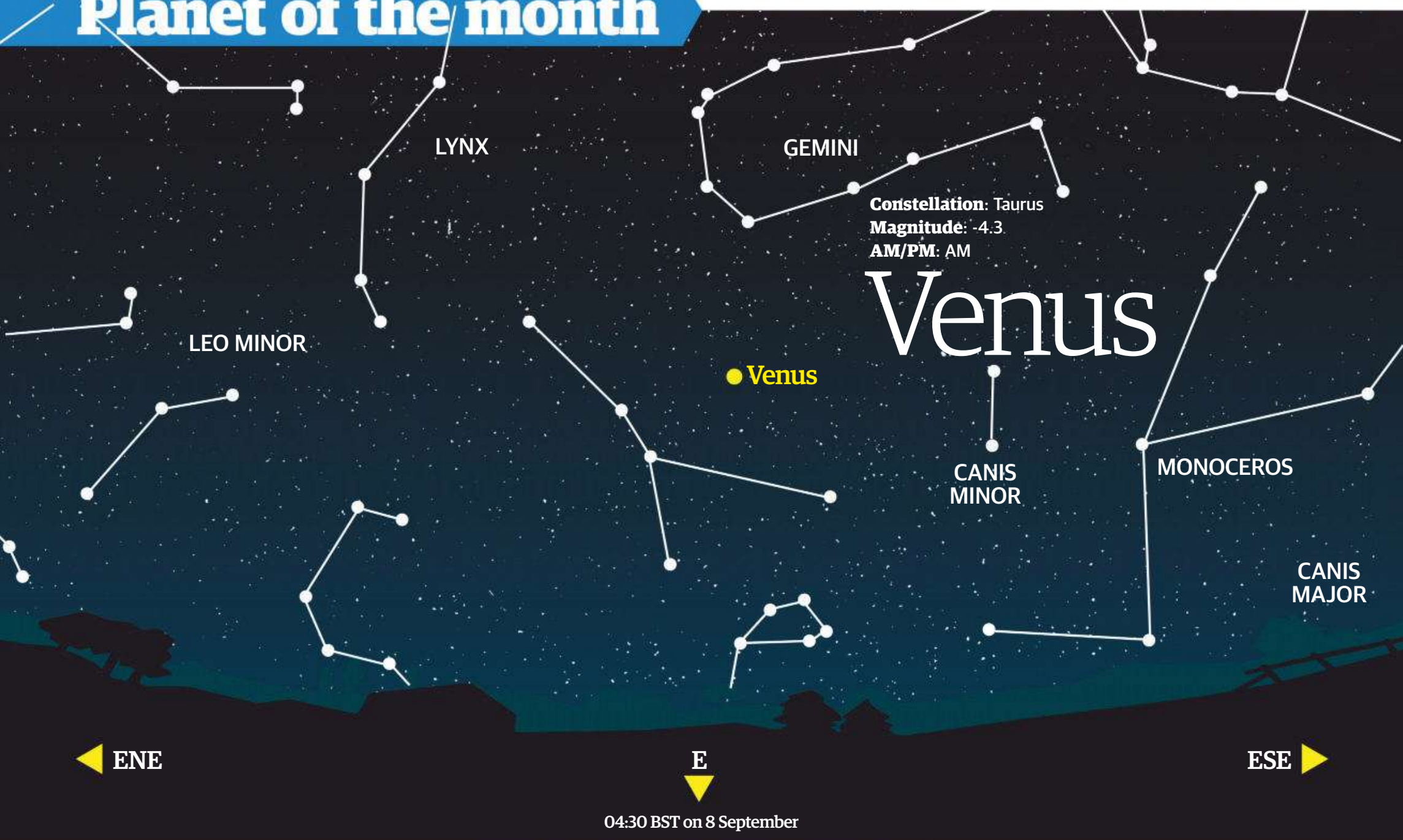
	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	13 AUG	09h 13m 41s	+17° 44' 37"	Cancer	-1.8	05:06	20:25
	20 AUG	10h 09m 21s	+13° 14' 07"	Leo	-1.8	06:01	20:26
	27 AUG	10h 58m 59s	+07° 59' 13"	Leo	-1.0	06:51	20:20
	3 SEPT	11h 43m 04s	+02° 35' 04"	Virgo	-0.5	07:35	20:08
	9 SEPT	12h 17m 24s	-01° 54' 57"	Virgo	-0.3	08:08	19:56
VENUS	13 AUG	06h 20m 07s	+20° 02' 23"	Orion	-4.3	01:59	17:46
	20 AUG	06h 49m 22s	+20° 07' 11"	Gemini	-4.3	02:00	17:48
	27 AUG	07h 19m 52s	+19° 50' 58"	Gemini	-4.2	02:04	17:49
	3 SEPT	07h 51m 12s	+19° 11' 27"	Gemini	-4.2	02:12	17:49
	9 SEPT	08h 18m 31s	+18° 18' 08"	Cancer	-4.2	02:22	17:47
MARS	13 AUG	01h 30m 01s	+05° 03' 16"	Pisces	-1.3	22:30	11:32
	20 AUG	01h 38m 15s	+05° 45' 12"	Pisces	-1.5	22:07	11:17
	27 AUG	01h 44m 26s	+06° 16' 23"	Pisces	-1.7	21:43	10:58
	3 SEPT	01h 48m 18s	+06° 36' 27"	Pisces	-1.9	21:17	10:36
	9 SEPT	01h 49m 33s	+06° 44' 36"	Pisces	-2.0	20:54	10:14
JUPITER	13 AUG	19h 20m 49s	-22° 31' 35"	Sagittarius	-2.7	18:52	02:54
	20 AUG	19h 18m 20s	-22° 36' 52"	Sagittarius	-2.6	18:23	02:23
	27 AUG	19h 16m 26s	-22° 40' 54"	Sagittarius	-2.6	17:54	01:53
	3 SEPT	19h 15m 09s	-22° 43' 40"	Sagittarius	-2.6	17:25	01:24
	9 SEPT	19h 14m 34s	-22° 45' 02"	Sagittarius	-2.5	17:01	01:00
SATURN	13 AUG	19h 55m 14s	-21° 04' 03"	Sagittarius	+0.2	19:17	03:38
	20 AUG	19h 53m 26s	-21° 09' 27"	Sagittarius	+0.2	18:48	03:08
	27 AUG	19h 51m 51s	-21° 14' 10"	Sagittarius	+0.3	18:19	02:38
	3 SEPT	19h 50m 31s	-21° 18' 09"	Sagittarius	+0.3	17:51	02:09
	9 SEPT	19h 49m 36s	-21° 20' 55"	Sagittarius	+0.4	17:27	01:44



This month's planets

Venus continues to dazzle at dawn, while gaseous duo Jupiter and Saturn still make a stunning pair before they dip below the horizon

Planet of the month



This month Venus will be visible in the east before dawn, looking like a brilliant, bright, blue-white spark in the sky, far brighter than any other planet or star in the sky at that time. Venus was already a very striking sight in mid-July, but as the mornings have passed it has become even more so, reaching its highest point in the morning sky on 8 September. Even leading up to its spectacular rise before dawn in September, Venus is easy pickings for early risers. On 13 August the planet reaches greatest western elongation, dazzling at magnitude -4.3.

It's ironic that such a beautiful, serene sight is in reality such a frightening and, some would say, ugly planet. Venus, the second planet out from the

Sun, is like a world invented for a science-fiction film. Its atmosphere of thick, curdled carbon dioxide would be lethally poisonous to us, and the incredible pressure on its surface would crush us too. Droplets of acid fall through its sky, but evaporate in the terrible heat long before reaching the ground. It will not be an interplanetary holiday destination anytime soon.

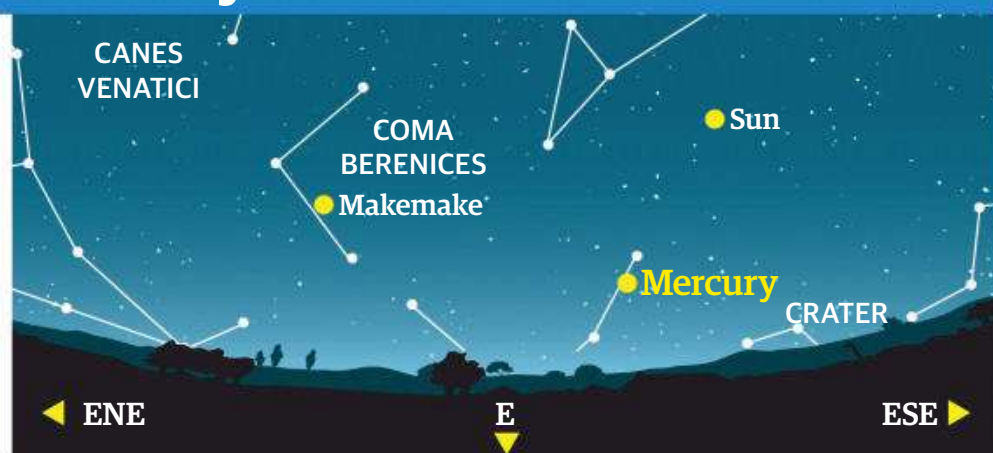
On 12 August 'Earth's evil twin' has reached dichotomy, a point where it is visible as a half phase through telescopes and binoculars. The phases of Venus are considered to be one of the most easy-to-spot aspects of the planet, and despite popular belief the second world from the Sun is still worthy of observation as sunlight

bathes the sky, especially since its sheer brilliance is tamed somewhat by a brighter backdrop. On the same morning the Perseid meteor shower reaches its peak of 120 'shooting stars' per hour. However, midnight is the prime time for catching them as the sky reaches optimum darkness for catching even the faintest meteors.

The best views of Venus can be had with the help of an orange, yellow or red filter, since the sky's blue light is filtered out. Venus' toxic atmosphere is what makes Venus shine so brightly in our sky. It's possible to capture features in the planet's thick atmosphere with the help of a dark blue or violet eyepiece filter through a telescope of at least ten inches or more.



Mercury 08:30 BST on 5 September



Constellation: Gemini

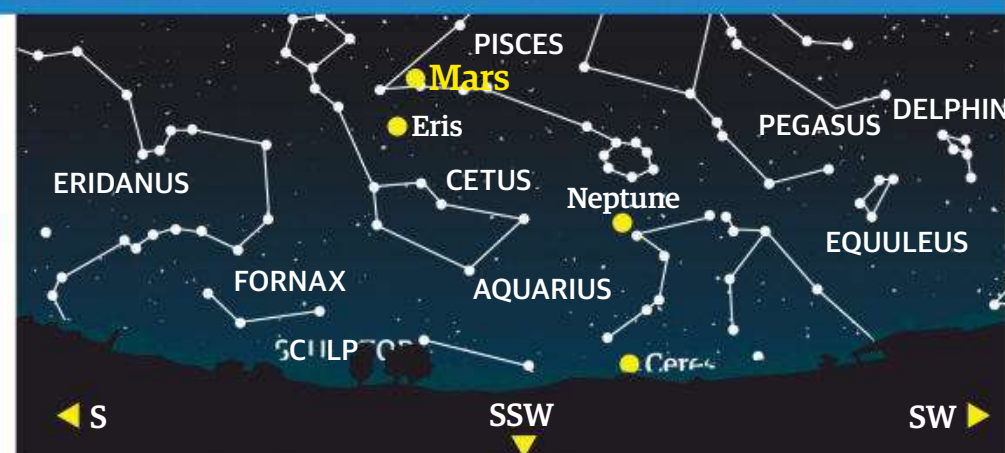
Magnitude: -0.1

AM/PM: AM

By mid-August Mercury will have brightened to an impressive magnitude -0.8, making it quite

obvious to the naked eye low in the sky before the sky begins to brighten. The innermost planet will be a challenge to observe due to being so close to the horizon before it sweeps out of view on 17 August.

Mars 04:30 BST on 30 August



Constellation: Cetus

Magnitude: -0.9

AM/PM: PM

At the beginning of August, Mars is no more than ten weeks away from opposition on 13 October. During

the month the Red Planet moves eastwards through Pisces, entering the southern boundary with Cetus. By the middle of August Mars will have brightened considerably to an impressive magnitude -1.2.

Jupiter 22:12 BST on 20 August



Constellation: Sagittarius

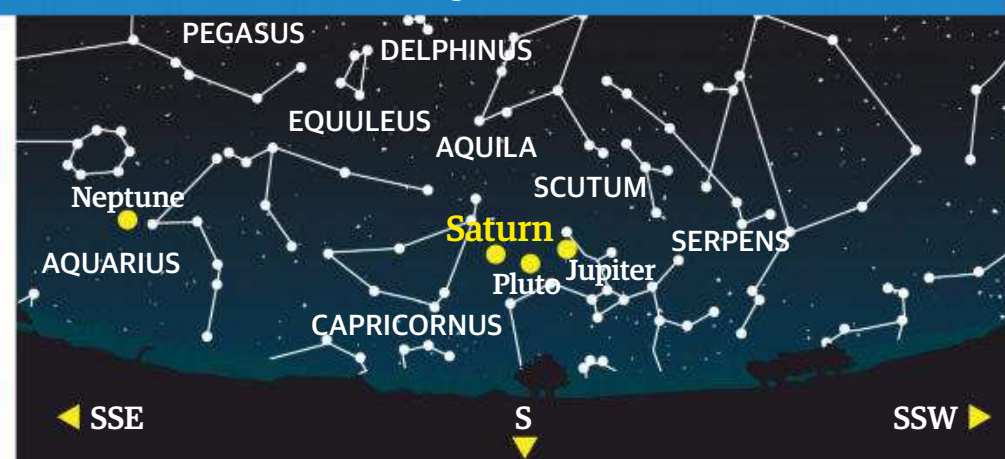
Magnitude: -2.7

AM/PM: PM

Jupiter will be a low-lying target for astronomers during our observing period. However, it still remains

a brilliant object for those with a clear horizon as a dazzling bright blue-white star to the unaided eye. Throughout August the king of the Solar System continues to put on a striking show alongside Saturn.

Saturn 22:30 BST on 23 August



Constellation: Sagittarius

Magnitude: +0.1

AM/PM: PM

Through August Saturn will be an evening object, appearing as a yellow-white star to the naked

eye. At this point in our observing period the golden-hued ringed planet has passed opposition in Sagittarius and rests to the upper left of the constellation's distinctive 'Teapot' asterism.

Neptune 23:48 BST on 25 August



Constellation: Aquarius

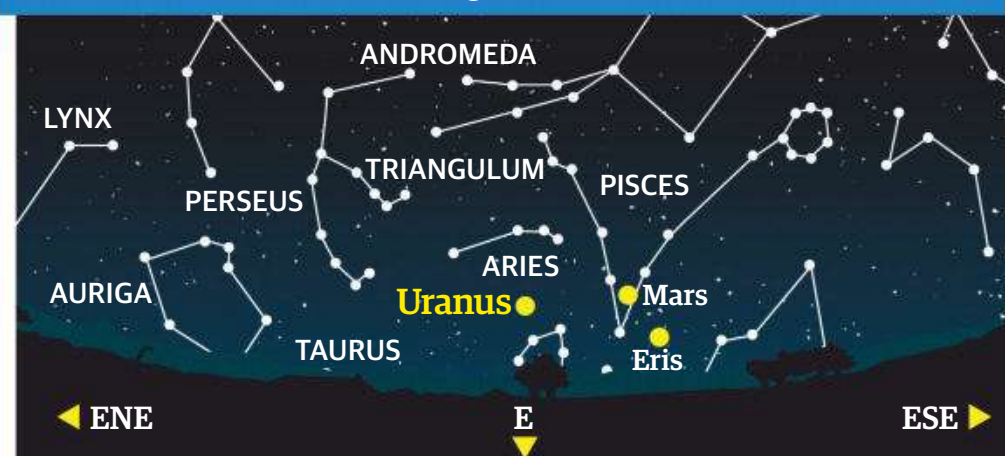
Magnitude: +7.8

AM/PM: PM

By mid-August the last planet in our Solar System will be rising in a bright sky at around 21:30. Being a

faint magnitude +7.8, Neptune is too faint to be seen using the unaided eye alone - binoculars will show a tiny blue-green star on the eastern side of Aquarius in a portion of the sky that's quite barren of stars.

Uranus 23:00 BST on 30 August



Constellation: Aries

Magnitude: +5.8

AM/PM: PM

By mid-August it will be rising as darkness begins to fall, setting in the early hours of the next morning.

Shining at magnitude +5.8 Uranus will technically be a naked-eye object, but if you don't have very good eyesight and a dark sky, you'll need binoculars or a small telescope to pin it down.



Moon tour

Mountains of Pico and Plato

To the south of Plato are mountains worth exploring with a telescope on warm summer nights

Summer is a great time to enjoy looking at the Moon. For one thing it doesn't climb very high in the sky, so you don't have to get a crick in your neck staring up at it. Also, the long, warm nights are perfect for moongazing: just lie back in a sun lounger or deck chair, relax and enjoy the sight of our natural satellite hanging above the trees or your neighbour's roof.

If you have a pair of binoculars you can see a surprising amount of detail on the Moon. They will show you its largest craters - huge holes blown out of its surface by the impact of asteroids millions or even billions of years ago. They will also show you its highest mountain ranges, some of which rival Earth's most beautiful. But the most striking sights in binoculars are the Moon's seas, or 'mare', which are not bodies of water but huge, flat plains of ancient lava which flowed out of the lunar surface like the yolk of an egg and spread across its terrain before freezing in the aftermath of enormous asteroid impacts.

One of the largest of these seas is Mare Imbrium, the 'Sea of Showers', which forms the bloated right eye of the 'Man in the Moon' when the phase is at its fullest. With the unaided eye, the lunar sea can be located at the top and centre of the Moon's disc but if you up your magnification through binoculars, you will see a small, dark circle or oval at the top of Mare Imbrium. This is a walled plain called 'Plato', and it's arguably one of the most famous features on the Moon.

When Plato is close to the terminator this month, focus your telescope on it, put in a high-power eyepiece and look just to its south. There you'll see what looks like a chain of some small rugged 'islands' out in the dark sea, close to the northern shore of Mare Imbrium. These stubs of rock are actually mountains, sticking up out of the lava plain of Mare Imbrium like pieces of bone or fossils exposed by the digging and brushing of patient archaeologists. You'll see them running from west to east in your eyepiece in a ragged chain. The more westerly ones form part of Montes Teneriffe, the Teneriffe Mountains, and were named after the island of Tenerife in the Canaries off the west coast of Africa.

Look a little further east and just to the south and you'll see a mountain sticking up out of the lava plain all on its own. This is Mons Pico, named after the volcano in the centre of Pico Island in the Azores. That volcano rises up 2.3 kilometres (1.4 miles) from the ocean, and the peak of its lunar namesake is 2.4 kilometres (1.5 miles) above Mare Imbrium, making it just a little higher.

Mons Pico is by no means the tallest or most impressive mountain on the Moon, but it is one of the most striking. When the terminator - the line between night and day - is either approaching or has just swept over it, Mons Pico can cast a long, very dark, very obvious shadow across Mare Imbrium which really makes it stand out. For this reason it's a firm favourite of many lunar observers.

Top tip!

The best time to see the mountains near Plato is when they are near the terminator, the point between night and day on the lunar surface.



Naked eye & binocular targets

Time to meet some of the summer Milky Way's treasures

1 Deneb (Alpha Cygni)

At magnitude +1.25 Deneb is the 19th-brightest star in the sky. A blue-white supergiant more than 100-times wider than the Sun, it is between 55,000 and 200,000 times more luminous than our own star. It will become the Pole Star around the year 9,800.

2 Great Globular Cluster in Hercules (Messier 13)

Messier 13 is an enormous cluster of stars 145 light years wide and 22,180 light years away. This ancient star cluster, which looks like an out-of-focus star in binoculars, contains around 300,000 stars and was discovered by the great astronomer Edmond Halley in 1714.

Cygnus

Draco

Corona Borealis

Serpens Caput

Hercules

Lyra

Vulpecula

Sagitta

Ophiuchus

Serpens Cauda

Aquila

Scutum

Scorpius

3 Cygnus X

Look below Deneb and you'll see what looks like a long, misty 'cloud' to the naked eye. Through binoculars this is revealed to be a haze of countless millions of stars, looking like diamond dust spilled on black velvet. Sweep along it slowly with your binoculars for stunning views.

4 Scutum Star Cloud (Messier 11)

Hanging low in the southern sky after midnight, the Scutum Star Cloud looks like a small, misty puff of cloud to the naked eye. Binoculars show it as a hazy smudge of stars with a brighter star cluster, Messier 11, embedded within it.

5 Messier 4

Look just to the right of the ruddy red star Antares and you'll see a smudge of light out of the corner of your eye. This is the ancient globular star cluster M4. It is 7,175 light years away and is more than 12 billion years old.

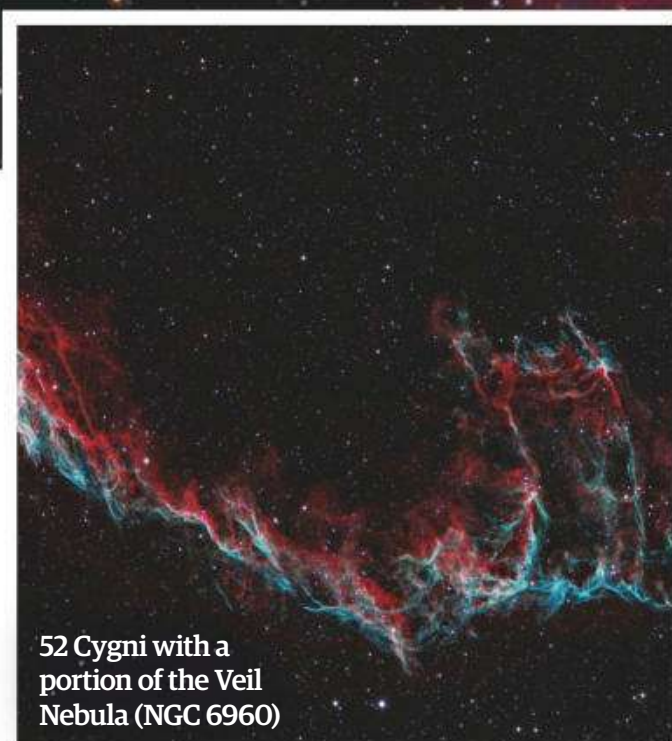
Deep sky challenge

Sizzling summer's clusters and nebulae

Glittering star clusters, a dead star's corpse and a beautiful double star can all be seen this month

Many sky-watchers think the summer sky is just too bright to allow for observation of faint and fuzzy deep-sky objects, but if you stay up late enough the sky is just dark enough to let you see some lovely sights through a telescope. Around one or two in the morning - providing the sky you're under isn't too marred by the glow of light pollution - a telescope will give you very pleasing views of some of astronomy's most famous objects.

Although the broad, frothy band of the Milky Way dominates the sky, running right through the centre of Cygnus (the Swan) or the Northern Cross, embedded in it are subtly coloured nebulae, regions where stars are born. Elsewhere you can see the ghostly remains of dying or dead stars, while even a small telescope will give you a beautiful view of some of the loveliest and most popular double stars in the whole sky.

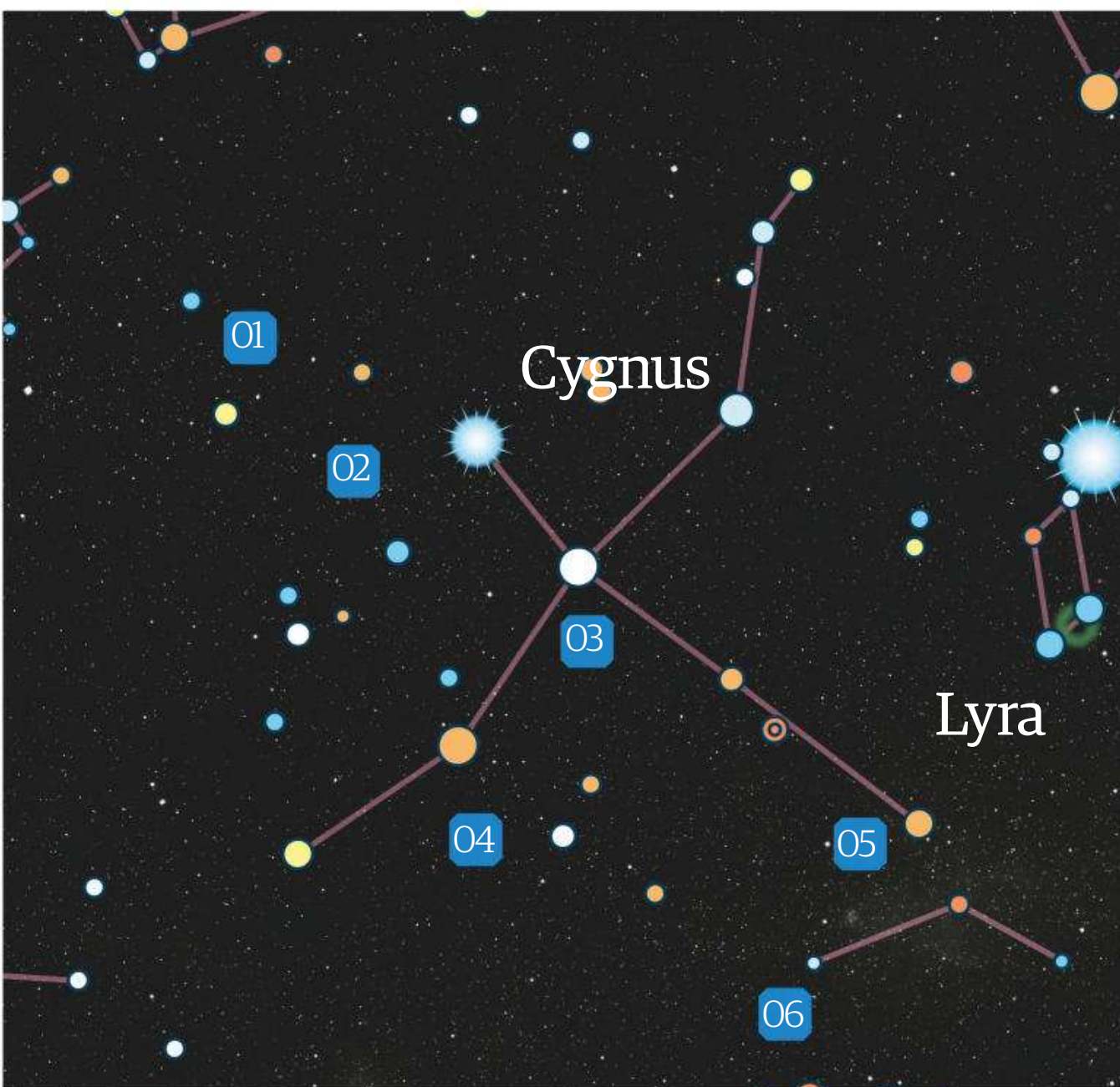


52 Cygni with a portion of the Veil Nebula (NGC 6960)

The Cygnus Wall in the North
America Nebula (NGC 7000)



Source: Wikipedia Commons © Chuck Ayoub



1 Messier 39

A loose open cluster, roughly triangular in shape and the same angular diameter as the Moon, it's best seen in small scopes using low magnification.

2 North America Nebula (NGC 7000)

Although this famous emission nebula covers as much sky as four full Moons and can be seen in binoculars, a telescope is needed to pick out its shape. Lower magnifications work best.

3 Messier 29

This magnitude +6.6 open cluster contains only a few scattered stars, forming the shape of an open box. Small to medium telescopes pick it out well from the background sky.

4 Cygnus Loop (Sharpless 103)

It consists of two arcs of faint gas, the remains of a star that blew up between 5,000 and 8,000 years ago. A medium-aperture telescope is needed to show structure and hints of colour.

5 Albireo (Beta Cygni)

One of the most beautiful double stars in the sky, any telescope splits Albireo into a 3rd-magnitude gold star and a magnitude +4.7 sapphire-hued star, lying 20" apart.

6 Dumbbell Nebula (Messier 27)

The famous Dumbbell Nebula is just a small smudge in small telescopes. Medium- and large-aperture telescopes show its twin lobes of blue-green gas.



The Northern Hemisphere

Aquarius and Pegasus grace the skies as we move into September

With the Sun setting not long after 19:00 this month, rich pickings can be had by those with even modest observing equipment. The end of September affords a last chance to catch the likes of Cygnus (the Swan) and Capricornus (the Sea Goat) and their wealth of deep-sky objects.

Look out for the 'Great Square' of Pegasus (the Winged Horse) rising in the west, while Cepheus (the King) appears in the northwest. In both a selection of binary stars can be split using small telescopes. Aquarius (the Water Bearer), Taurus (the Bull) and Orion (the Hunter) offer globular and open clusters along with glowing star-forming regions, which are a breeze to pick up through binoculars and even the naked eye with low light pollution.

Using the sky chart

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

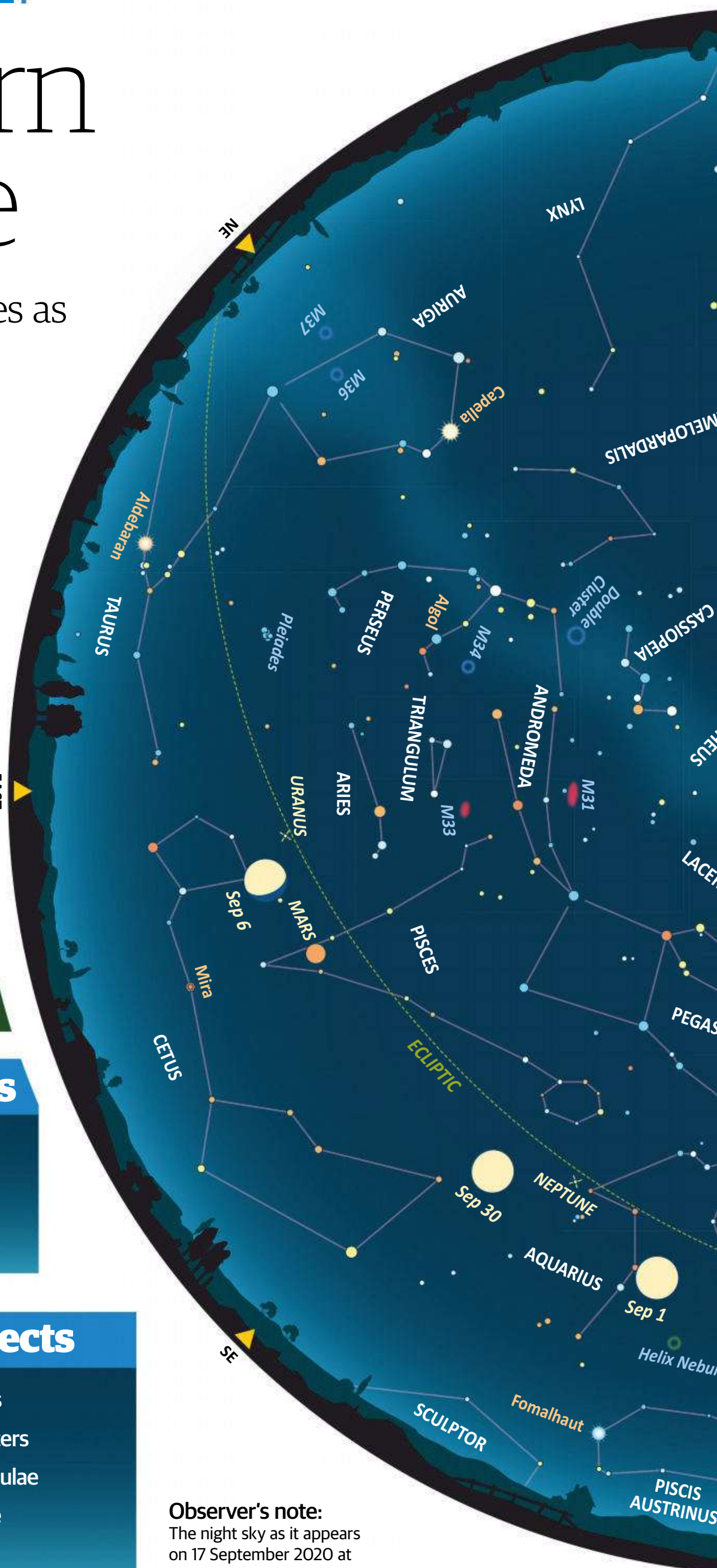
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| • O-B | • G |
| • A | • K |
| • F | • M |

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

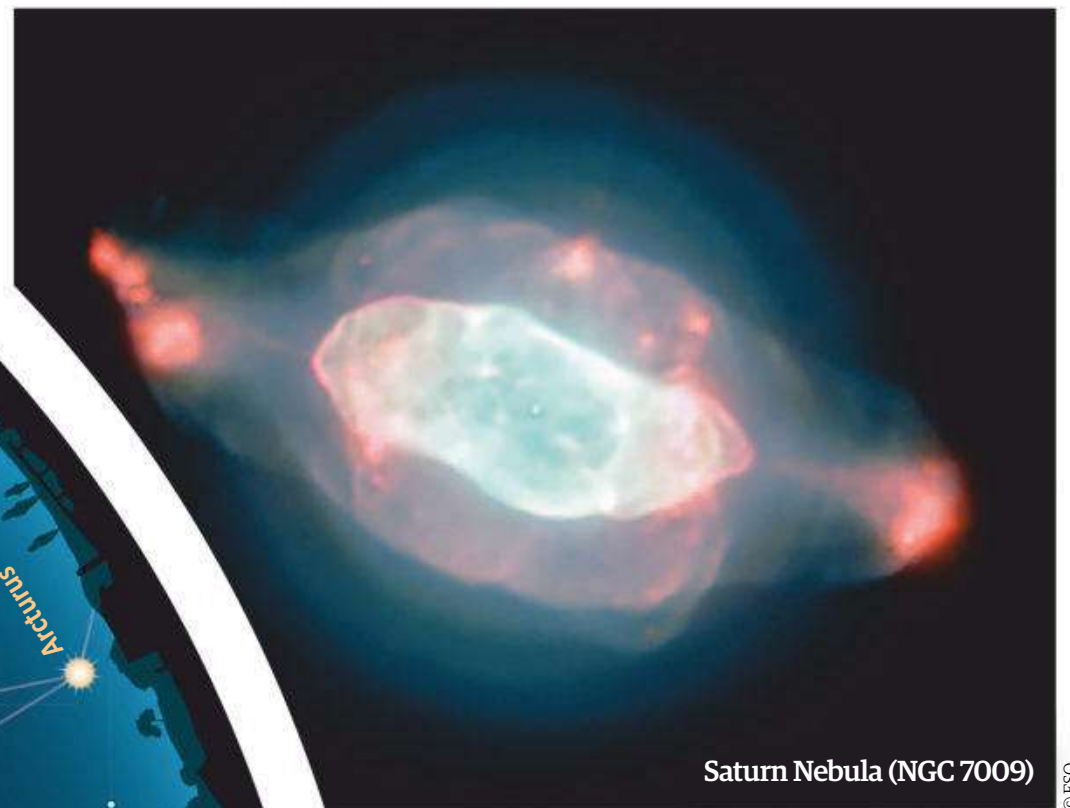


Observer's note:

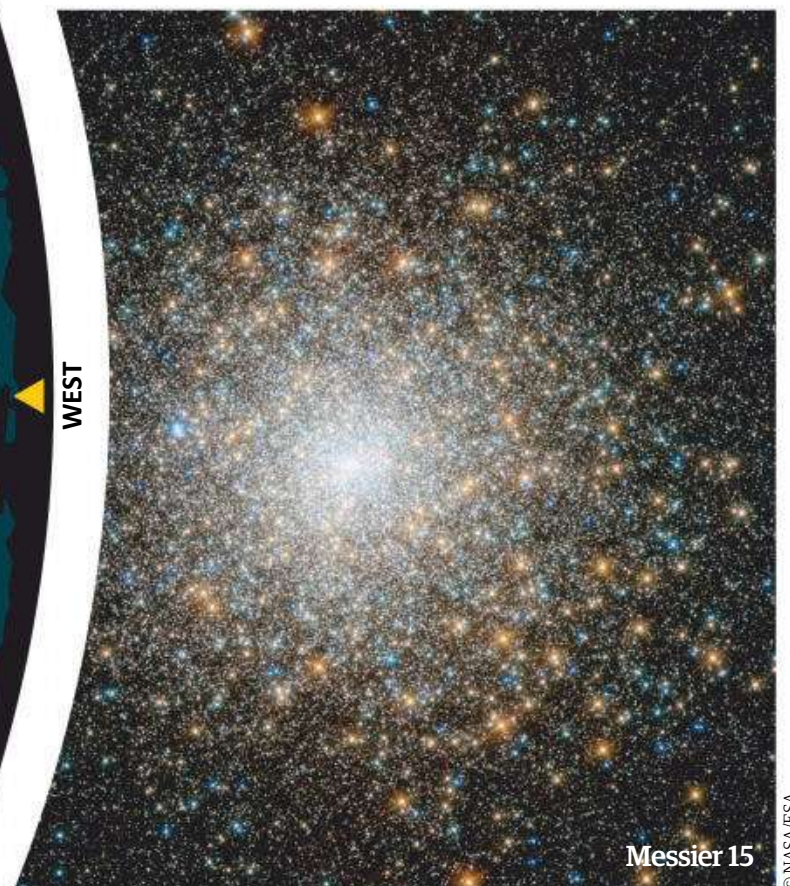
The night sky as it appears on 17 September 2020 at approximately 22:00 (BST)



The Northern Hemisphere



© ESO



© NASA/ESA



Source: Wikipedia Commons © Adam Evans



Sky-Watcher Explorer-130PS AZ PRONTO

Perfect for astronomers on the go, this excellent Newtonian has been built with the beginner in mind

Telescope advice

Cost: £225 (approx. \$282.47)

From: Optical Vision Ltd

Type: Newtonian

Aperture: 5.11"

Focal length: 25.59"

Best for...



Beginners



Small budgets



Planetary viewing



Bright deep-sky objects



Basic astrophotography

A telescope that can be easily transported to sites untouched by light pollution has great appeal whether used by a beginner or a more seasoned astronomer, and that's exactly the sort of telescope Sky-Watcher's Explorer-130PS is, fitting the bill nicely as a 'grab-and-go' instrument. The telescope and its AZ PRONTO mount are a compact and light package. Assembly and operation are user-friendly in the hope of providing a welcoming introduction to observing the night sky, making it an ideal telescope for those new to touring the heavens.

It uses a Newtonian reflector design that employs a parabolic primary mirror to collect and focus the light and a flat secondary mirror to reflect it to the eyepiece. This design requires collimation to align the two mirrors accurately with one another and the eyepiece. To make life easier for beginners, a large chunk of this potentially perplexing process has been removed. The telescope has a fixed mirror cell for the primary mirror which is collimated at the factory, so it'll only require occasional adjustments to the secondary mirror, for which a suitable Allen key is supplied. Upon delivery the review telescope was in excellent collimation and produced well-formed stars during this test - it really did work well straight out of the box. The AZ PRONTO mount didn't disappoint and was quick to assemble, providing a sturdy platform for the

telescope. An accessory tray for your eyepieces also serves to help stabilise the entire set-up - we discovered that there was minimum shaking during our observations and sufficient resistance against the light breeze that picked up throughout the course of the evening. Adjustments with the mount are smooth and it's easy to keep objects centred in the tube's field of view.

The Explorer-130PS also comes with a pier extension to keep the telescope from clipping the tripod legs while slewing - something that got a lot of use throughout our review. The Explorer-130PS' steel optical tube is finished in a high-gloss black with a silver-flecked finish - making it aesthetically appealing - and cradled in two substantial felt-lined tube rings, which are attached to a Vixen-style dovetail bar. The dovetail bar isn't used to attach the telescope to the mount. Instead a bolt on the mount is screwed into a matching threaded hole

Below: This scope is simple to assemble, easy to use and gives good views of some of the most popular targets

"THE TELESCOPE AND ITS AZ PRONTO MOUNT ARE A COMPACT AND LIGHT PACKAGE, AND ASSEMBLY AND OPERATION ARE USER-FRIENDLY"

in the base of the bar - pleasingly, no slippage was experienced during our review of this feature.

A rather basic, plastic, single-speed rack-and-pinion focuser completes the optical tube, but despite some initial reservations we found this to be effective in use. With it we were able to achieve focus amazingly quickly and easily. The supplied red dot finder is certainly an excellent choice, especially for beginners, as it's so easy and intuitive to use. Over a smaller optical finderscope, we relied on it extensively for star hopping to a selection of deep-sky objects that peppered the mid-summer evening sky.





Top: Two eyepieces are supplied: one 25mm and one 10mm

Main: The telescope is well built and the tripod is sturdy

Left: Adjustments are smooth – it's easy to keep objects centred in the field of view

With its focal length of 650mm, the Explorer-130PS is a good compromise for observing a wide range of objects in the Solar System and deep-sky categories. Taking our observations until dawn, we enjoyed some excellent views of Mars in the small hours of the morning, then a variety of open clusters, boasting its wide-angle capabilities. In both the 25mm and 10mm eyepieces the rugged lunar surface was a wonderful sight through this telescope, sure to delight those who have only just been introduced to astronomy.

Overall the scope and mount package was a pleasure to use. It's simple to assemble and easy to get to grips with, while its optical system gives good views of popular targets. With no immediate teething faults, the Explorer-130PS is a highly recommended instrument for the beginner.

Jedidah Isler

Isler's fervour for blazars led to her becoming the first African American woman to receive a PhD from Yale University

Jedidah Isler is an exceptional astrophysicist and an excellent modern-day role model for any young women of colour, who are pursuing a career in the disciplines of science, technology, engineering and mathematics (STEM). Her studies of the universe in a field that continues to face racial and gender bias are nothing short of truly remarkable.

In 2015 Isler presented a TED talk where she spoke eloquently about race and gender within STEM, including her experiences when working towards her doctorate. This talk heavily revolves around metaphorical intersections and the liminal space in which great things happen. Her examples include how stars are born at the intersection between dust and gas, but also how she has lived her life in the liminal space between dreams and reality, race and gender, poverty and plenty, science and society.

At the age of 12, Isler knew she wanted to be an astrophysicist, and it was this passion that drove her forward, even when things looked bleak. At that time, according to Dr Jamie Alexander's archive of African-American women in physics, there were only 18 black women that had received a doctorate within a physics-related discipline in the United States. A year before Isler's birth, a black woman received a doctorate in an astronomy-related discipline, becoming the first to do so.

Roughly 60 per cent of women of colour have to overcome a financial barrier in order to pursue their education, and Isler was one of them. Luckily Norfolk State University, Virginia, provided her with full funding, and she went on to receive a bachelor's degree in physics. After two years out of school, she then went on to gain a master's degree via the help of the Fisk-Vanderbilt Master's-to-PhD Bridge Program. This led her to Yale University in Connecticut.

During her studies Isler was subjected to some cruel behaviour that she says ostracised her, and would certainly discourage anyone from wanting to continue. This is sadly not the first time a woman of colour has had to endure such treatment in a STEM-related environment. This has been confirmed in a recent study, where



Isler studied blazars extensively in pursuit of her PhD

all 60 women of colour interviewed by Joan C. Williams, professor of law at the University of California's Hastings College of the Law, said that they were subject to racialised gender bias in STEM - a horrible statistic when considering the supposed 'intelligence' of the people in the field and at such a prestigious university.

This did not deter Isler's dreams of becoming an astrophysicist, however, and she continued her studies and research into blazars. After studying these mind-bogglingly enormous black holes, which fall under the astrophysical genre of Active Galactic Nuclei (AGN), she became the first African-American woman to receive a PhD in astrophysics from Yale University in 2014. Her thesis is titled *In Like a Lamb, Out Like a Lion: Probing the Disk-Jet Connection in Fermi Gamma-Ray Bright Blazars*.

Isler is now an assistant professor of astrophysics at Dartmouth College, Hanover, New Hampshire, and she continues to strive for improvement when it comes to the treatment of women of colour in STEM subjects. In fact, she is also the founder, executive producer and host of Vanguard: Conversations with Women of Color in STEM, or VanguardSTEM.

Editorial

Editor-in-Chief **Gemma Lavender**
gemma.lavender@futurenet.com

Art Editor **Jonathan Wells**

Staff Writer **Lee Cavendish**

Production Editor **Nikole Robinson**

Research Editor **Baljeet Panesar**

Senior Art Editor **Duncan Crook**

Photography **Oilly Curtis**

Contributors

Stuart Atkinson, Charles Q. Choi, David Crookes, K. E. Saavik Ford, Chris Hadfield, Robin Hague, Keisuke Harigaya, Elizabeth Howell, Masateru Ishiguro, Jack Madden, Patrick Michel, Mara Johnson-Groh, Adam Mann, Jonathan O'Callaghan, Lynnae C. Quick, Mario Spera, Colin Stuart, Doris Elin Urrutia, Hanneke Weitering

Cover images

Getty, Tobias Roetsch; Adrian Mann; NASA

Photography

Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons; All copyrights and trademarks are recognised and respected

Advertising

Media packs are available on request

UK Commercial Director **Clare Dove**

clare.dove@futurenet.com

Senior Advertising Manager **Amanda Burns**

amanda.burns@futurenet.com

0330 390 6036

Account Manager **Garry Brookes**

garry.brookes@futurenet.com

0330 390 6637

International Licensing

All About Space is available for licensing. Contact the Licensing team to discuss partnership opportunities.

Head of Print Licensing **Rachel Shaw**

licensing@futurenet.com

Subscriptions

Enquiries www.myfavouritemagazines.co.uk/en/contact

UK orderline & enquiries **0344 848 2852**

Overseas order line & enquiries **+44 (0)344 848 2852**

Online orders & enquiries www.myfavouritemagazines.co.uk

CRM Director **Louise Dudfield**

Circulation

Head of Newstrade **Tim Mathers**

Production

Head of Production **Mark Constance**

Production Project Manager **Clare Scott**

Advertising Production Manager **Joanne Crosby**

Digital Editions Controller **Jason Hudson**

Production Manager **Frances Twentyman**

Management

Chief Content Officer **Aaron Asadi**

Commercial Finance Director **Dan Jotcham**

Brand Director **Evan Kypreos**

Head of Art & Design **Greg Whitaker**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

All contents © 2020 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.



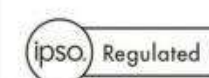
We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill and paper hold full FSC and PEFC certification and accreditation.



Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR) www.futureplc.com

Chief Executive **Zillah Byng-Thorne**
Non-executive Chairman **Richard Huntingford**
Chief Financial Officer **Rachel Addison**

Tel +44 (0)1225 442 244





QUICKBUILD

- Stickers Included
- Rolling Wheels
- Pre-Coloured
- Push Fit



J6033
Jaguar I-PACE eTROPHY



Jaguar I-PACE eTROPHY

Build an Iconic Model

The all-electric Jaguar I-PACE has completed an historic treble at the 2019 World Car Awards. Not only has it won the coveted 2019 World Car of the Year and World Car Design of the Year titles, it has also been named World Green Car.

The I-PACE is the first model ever to win three World Car titles in the 15-year history of the awards.

This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. You can recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

The dramatic, cab-forward profile, short overhangs and taut, muscular haunches give it a sense of drama which set it apart from other SUVs, which when building with the 40 pieces included you will see as the car grows before you.

Jaguar and the leaper device are trademarks owned and licensed by Jaguar Land Rover Limited.



Collect them all! Check out the rest of the range online.

No glue!
No paint!
Just build!



J6019 **Lamborghini Aventador**



J6025 **Yellow VW Beetle**



J6020 **Bugatti Veyron**

Sky-Watcher®

Be amazed.

POPULAR BEGINNER
& INTERMEDIATE
NEWTONIAN
REFLECTORS

Sky at Night
MAGAZINE
GROUP TEST
WINNER

ASTROLUX

76mm f/9.2 REFLECTOR

SRP
£89.99

Sky at Night
MAGAZINE
GROUP TEST
WINNER

SRP
£165

"The optics were so good....
the review instrument
certainly delivered in every
important respect"
BBC SKY AT NIGHT MAGAZINE

SKYHAWK-1145P (EQ1)

114mm f/4.4 PARABOLIC REFLECTOR

EXPLORER-130 (EQ2)

130mm f/6.92 REFLECTOR

"This telescope made observing
the night sky enjoyable....great
views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-150P (EQ3-2)

150mm f/5
PARABOLIC REFLECTOR

"Good for advanced observing...
Saturn was a stunning sight"
BBC SKY AT NIGHT MAGAZINE

SRP
£389

Sky at Night
MAGAZINE
HIGHLY
COMMENDED
87%

EXPLORER-150PL (EQ3-2)

150mm f/8 PARABOLIC
REFLECTOR

SRP
£389

EXPLORER-200P (EQ5)

200mm f/5 PARABOLIC REFLECTOR

"Passed all our tests with flying
colours and was a delight to use
both optically and mechanically"
BBC SKY AT NIGHT MAGAZINE

Sky at Night
MAGAZINE
GROUP TEST
WINNER

SRP
£585

SKYLINER-150P CLASSIC

153mm f/7.8 PARABOLIC DOBSONIAN

SRP
£259

"Turning to Saturn, the view really took our
breath away....The Skyliner was a joy to use"
BBC SKY AT NIGHT MAGAZINE

SKYLINER-200P CLASSIC

203mm f/5.9 PARABOLIC DOBSONIAN

SRP
£349

Sky at Night
MAGAZINE
HIGHLY
COMMENDED
93%

SKYLINER- 250P CLASSIC

254mm f/4.7
PARABOLIC
DOBSONIAN

SRP
£519

Sky at Night
MAGAZINE
★★★★★
REVIEWED IN
Issue 111
August
2014

HERITAGE-100P

100mm f/4 PARABOLIC
DOBSONIAN

SRP
£115

HERITAGE-76

76mm f/4 DOBSONIAN

SRP
£62.99

SRP
£179

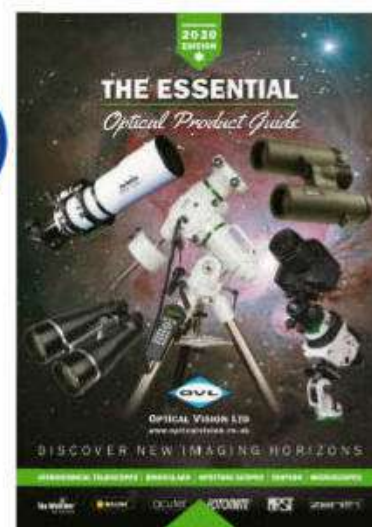
HERITAGE-130P FLEXTUBE™

130mm f/5 PARABOLIC DOBSONIAN

HERITAGE-150P FLEXTUBE™

150mm f/5 PARABOLIC
DOBSONIAN

SRP
£219



Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:

www.opticalvision.co.uk
info@opticalvision.co.uk

Email for 88 Page
FREE
Catalogue